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THE PORT OF LONDON

AND THE

THAMES BARRAGE

A SERIES OF

EXPERT STUDIES AND REPORTS

On the conditions prevailing in the Tidal River and Estuary of the Thames; dealing especially with its Geological, Engineering, Navigation, Sanitary, Trading, and Commercial Aspects, and the effects upon these of various proposals which have been made for improvement of the Tidal River as the Port of London

COMPRISING INDEPENDENT STUDIES AND INVESTIGATIONS BY THE ENGINEER TO THE THAMES BARRAGE COMMITTEE

T. W. BARBER, M.Inst.C.E.

AND BY

C. J. DIBDIN, F.I.C., F.C.S., F.R.M.S., Etc.,
Vice-President of the Society of Public Analysts, etc., etc

E. T. HENNELL, M.Inst.C.E.

CLAYTON BEADLE, F.R.Met.Socy., F.C.S.,
Secretary and Chemist to the Underground Water Preservation Association

D. URQUHART,
Thames Ironworks, Canning Town.

ISSUED BY THE THAMES BARRAGE COMMITTEE

London
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PROPOSED THAMES BARRAGE AT GRAVESEND. PERSPECTIVE VIEW.

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SECTION I.

INTRODUCTION.

The Committee formed in 1903 to promote a public enquiry into the proposed Barrage across the Thames in the neighbourhood of Gravesend—thus converting the whole of the lower river into a freshwater lake—having so far failed to attain its main object, has instituted a series of expert enquiries and studies into the various questions which have arisen and are involved in the Barrage proposal.

As it is practically certain that in the next Session of Parliament proposals will be submitted dealing with the Port of London, it is hoped that, whatever the proposals may be, they will not be such as to exclude the possibility of a thorough enquiry by experts appointed or approved by the Board of Trade into the whole Barrage question.

Unfortunately for the tidal Thames as a River and Port, the average Londoner knows it not. In Hamburg, in Antwerp, the Port is the life of the city. If you improve the Port you practically improve the business of every ratepayer, hence the energy displayed there, so that any proposal for improvement which is *prima facie* sound is certain to be carefully examined by the responsible technical advisers of the Port Authorities, and capital is always forthcoming to carry out such works as may be recommended by those advisers.

In London, on the other hand, only a relatively small proportion of the business world has any direct connection with the Port, and the West End knows probably less about the Port of London than it does about Hamburg.

The Thames Barrage Committee, in publishing the following expert studies feels that it is fulfilling a public duty by supplying information not otherwise accessible which should be of interest, not only to those who are directly affected by the trade of the river but also to all who wish to see the premier port of the world maintain its position and, if possible, improve it.

In the following Studies and Reports the technical questions have been chiefly dealt with. It would have been impossible to consider the subject from the point of view of the various special interests which would be affected, such as the Dock Companies, the Wharfingers, the Barging trades, the owners of riverside properties, &c. If it is once shown that the proposal is a practical one, which, if carried out, would offer greater advantages than the present system, or rather lack of system, then will be the time to weigh carefully the effect of the scheme on vested interests, and the cost of any fair compensation as against the advantages to be secured.

Short History of the Port of London.*

Page 16.—"The Port of London is still, as it has been for at least 200 years, the greatest in the world in respect of the amount of shipping and of goods which enter it. Statistics show a constant growth in the volume of trade, although the rate of increase has not been so rapid in the more recent years as it was in some former times. Its trade has grown in tonnage of vessels entering the Port from 6 millions in 1860 to 15½ millions

* From the Report of the Royal Commission on the Port of London.

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in 1899, and in the value of goods imported from 124 millions in 1872 to 164 millions in 1899. The exports in the latter year amounting to 88 millions, and its re-exports of foreign goods to 34½ millions. There is no doubt that the bulk of the imports entering the Port are consumed or used by the vast population immediately surrounding it, and that the growth of the trade of the Port in recent years is chiefly due to the increase in the numbers and wealth of the inhabitants of London and its environs."

Page 23.—"The existence upon the Thames of the greatest market and centre of consumption in the world, has, it is contended, bestowed upon the Port a huge practical monopoly. London was sure of a trade of which rivals could not deprive it, and in consequence, had not the usual incentives to effect improvements. Other ports, in keen competition with each other for the general world-trade, have improved their organisation and physical advantages in recent years, while London has, in these respects, remained much more nearly stationary. Hence, it is suggested, both the inland and re-export trade of London may have lost ground, relatively to other ports, in consequence of the improvements in other maritime cities of the United Kingdom and in adjacent countries. So far as relates to the re-export of foreign and Colonial produce the figures seem, to some extent, to correspond with this view."

"Formerly London was a distributing and collecting Port, as being the world's trade focus, the world's market. The cargoes came to the biggest market. The low countries and the Continent bought in London and sent goods to London for shipment. London was the 'Goods Exchange' for Europe to a large extent. Foreign produce formerly was largely a prohibitive luxury only available to the few. Foreign ports had no use for shiploads; they wanted parcels; shiploads came to London. The development of production, cheapening of transport, abolition of duties, increase of population, spread of wealth, and the introduction of steam factories altered the situation. The Continent became able to swallow whole shiploads; but Continental ports being undeveloped and unhandy, and the force of ancient usage being very strong, cargoes continued to come to London. In 1863 the abolition of the Scheldt dues threw open Antwerp, which at once began to compete with London. The Suez Canal was opened, trade increased enormously, and the ships began to be ordered, with full cargoes, to Antwerp. The new departure extended to Hamburg, Rotterdam, Havre, and other places, and all these ports began competing furiously with one another and all with London. Moreover, the practically new ports of Marseilles, Genoa, and Trieste now intercept cargo which formerly passed through the Straits of Dover, and these ports are greatly developing. This competition, powerful as it is, is still in its infancy. Continental ports are spending lavishly on improvements, and already British shipowners prefer Antwerp to London, and would as soon go even to Hamburg as to London. It seems inevitable that the business of London as a Port of distribution will decline."

These extracts state clearly the tendency of the trade of the Port and its changes, and indicate the probable future conditions under which it will be conducted, to which may be added the fact that sailing ships and small vessels generally

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are rapidly becoming disused and obsolete, and that increase of tonnage and draught are prominent conditions to be met and provided for in future changes.

Thus, in 1840, the number of all vessels registered in the Port of London was 2,955, with a tonnage of 619,920, but in 1901 the numbers were respectively 3,027 and 1,850,809. While in the same period sailing vessels declined from 2,838 in 1840 with a tonnage of 582,460 to 1,299 in 1901 with a tonnage of 255,870 (Board of Trade Returns). On the other hand, steamships increased in the same period (1840 to 1901) from 220 with a tonnage of 37,257 to 1,728 with a tonnage of 1,594,939.

These facts, briefly stated, clearly show the changes in the circumstances of the shipping world-trade of London, and point to the provision of greatly increased accommodation, both in navigation facilities and in means of dispatch to deal effectively with the enormous growth of trade and with its economical distribution.

These salient features of London's Port are more fully dealt with in the Section on the Trade of the Port on p. 121, where the subject is fully elucidated.

The changes and growth of trade have inevitably led to changes of management and the machinery of trade, and also have given rise to grave and increasing complaints, which have led up to organised efforts to introduce improvements more commensurate with the newer types of vessels, and providing for more rapid handling of cargoes.

These took effect in Reports of the Lower Thames Navigation Commission, 1895–1896; Reports of the Select Committee of the House of Commons on the Pilotage Bill of 1870; the Thames Traffic Committee of the Board of Trade, 1878–1879; the Select Committee of the House of Commons on Pilotage, 1888, and in the discussions on numerous Dock and other Bills in the House, and more recently in the Report of the Royal Commission on the Port of London, 1902, which latter was an exhaustive and full enquiry into the Dock and Shipping Trade, at which every interest was fully represented—except the Barrage Proposal.

The Barrage Proposal.

It is unfortunate that evidence offered in favour of this proposal was refused a hearing on the ground that it was outside the scope of the reference, because as a result the Report must necessarily be limited to one side of the subject, based wholly upon the scheme of dealing with the river as a tidal one, as though no other method were possible. Its chief value, therefore, is its mass of statistics and facts, in which respect it is admirable and of the greatest service in considering the future treatment of the river.

The following is the text of the reference, and manifestly does not exclude the Barrage question :—

"*WHEREAS We have deemed it expedient that a Commission should forthwith issue to inquire into the present administration of the Port of London and the water approaches thereto; the adequacy of the accommodation provided for vessels, and the loading and unloading thereof, the system of charge for such accommodation and the*

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arrangements for warehousing dutiable goods; and to report whether any change or improvement in regard to any of the above matters is necessary for the promotion of the trade of the Port and the public interest."

The omission has given rise to a strong agitation in favour of an independent enquiry under official auspices into the merits of the proposal, which, on the face of it, seems to offer enormous advantages all round, as compared with those of the Royal Commission, and which we submit are fully substantiated in the following pages.

The Barrage Committee was formed in 1903 with Sir Thomas Brooke-Hitching, L.C.C. and C.C., as Chairman, and included a large number of City merchants and others, and has continued its labours and published its literature without assistance or reward from any river interest. It has promoted three Bills before Parliament to draw the attention of the authorities and river interests to its claims and to the need for enquiry.

The recommendation of the Royal Commission to purchase the Dock Companies' undertakings has had the effect of creating an interest opposed to the Barrage, the Dock Companies considering that a Barrage would prevent purchase, and by making the river into a vast dock injure their monopoly and diminish the value of their stock. This question also is fully dealt with further on p. 160, it is only necessary here to state two obvious facts—first, that the public good should be paramount, and second, that Parliament is not likely to deal unjustly with the Dock Companies in any settlement that may be arrived at.

But, outside of the Dock Companies, a very great amount of interest has been aroused, and very little—except passive—opposition has been manifested. Numerous enquiries have been made, and some difficulties presented, to which more or less effective answers have been given; and the chief purpose of the Committee in publishing the following Reports and studies is to deal with these objections by competent experts, appointed to study each of them separately and fully, with all information obtainable from every reliable source—chiefly official—and to point out to what extent they are justified and in what way and at what cost they may be averted or neutralised.

Speaking generally, the objections represent fears rather than facts; the present state of the tidal water, the vast volume of shipping and numerous interests concerned and their accommodation efficiently, naturally and inevitably strike the ordinary observer as mountainous difficulties almost impossible of removal. To what extent and in what manner it is proposed to remove them the Reports which follow will show, but there can be no two opinions—after perusing the Report of the Royal Commission on the Port of London—as to the need for a drastic and effective change.

The present disabilities which hamper and retard trade in the Port may be briefly summarised as follows:—(*a*) Insufficient depth of water in the river for the increasing size and tonnage of ships. (*b*) Tide-waiting at Gravesend and at the dock entrances, inward and outward. (*c*) Excessive dues. (*d*) Vexatious restrictions owing to conflicting and overlapping authorities in the river. (*e*) Excessive cost of barging, pilotage, and labour in loading and discharging. (*f*) Loss of time at the Port.

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(*g*) Dangerous navigation due to tides, bends in the river, narrow channel, fogs, and the crowded state of the river. That these complaints are well founded is generally admitted, and their list might be easily extended.

Remedies Proposed.

The Royal Commission on the Port of London, the Board of Trade as representing the Government, the Thames Conservancy, the Dock Companies and others recommend the deepening of the river by dredging as a remedy for (*a*) and as a partial remedy for (*b*) and (*f*). As to (*c*) no remedy seems to be proposed by either, but rather an increase of dues, or in lieu thereof a charge upon the rates of London through the London County Council. Partly to amend (*d*) it has been proposed by all the above authorities, except the Thames Conservancy, that a Port Trust should be created to control the river, instead of the present conflicting authorities of the Thames Conservancy, Trinity House, the City Corporation, and the Watermen's Company. But as to (*e*) there is no suggestion of amendment, nor is it expected that the proposed deepening of the river will materially improve the dangerous navigation (*g*).

It is evident that all these proposals are based upon—and in fact assume, as matter of common knowledge—the possibility of dredging the river to the depth now found necessary for the increased draughts of the larger class of vessels which are becoming the common traders of the Port, and this in the face of the many warnings uttered by witnesses before the Royal Commission, not called specially to give evidence on this question.

In Section XIII. on p. 41 this subject is exhaustively treated, and the baselessness of the proposal made evident, but this being so, what becomes of the recommendations founded on it? Where is the use of a new Port Trust to purchase the Docks and hand them over to a Municipal Authority having no knowledge of dock business, if the river cannot be deepened and proper provision made for navigation, reduction of charges and delays, in order to enable the shippers to compete with other ports? It seems hardly credible that this obvious phase of the subject should have received such scant attention by the Commission. Its recommendations were as follows:—

Page 307.—"To sum up then our recommendations upon these points, we propose that the Port Authority should be empowered:—

"(1) *To retain the powers now possessed by the Thames Conservancy of levying dues upon ships which enter the Port;*

"(2) *To levy, subject to the statutory maximum, dock tonnage dues upon all ships which enter the docks, and to fix charges upon goods landed in the docks other than those dealt with on overside conditions;*

"(3) *To levy annual licensing dues upon barges;*

"(4) *To impose dues upon import goods entering the Port, except goods for transshipment, subject to maxima for different classes;*"

none of which recommendations touch the main difficulties we have enumerated.

This Report, which was to settle the future of the Port of London, has settled nothing, and it is becoming evident that no settlement will be arrived at by attempts to patronise any one interest, where all are at variance. Hence we have had the

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Government Port of London Bill, 1903, which, after two years' discussion, was abandoned. This was followed by a Thames Conservancy Bill (Thames Conservancy Bill, 1905), a London County Council Bill (London Port and Docks Commission Bill, 1905), and, for the present Session, a Bill promoted by the London and India Dock Company all drawn to favour particular interests and incidentally spend enormous sums at the cost of the ratepayer, none of which have satisfied Parliament or succeeded in silencing interested opponents.

There have, of course, been numerous schemes suggested, mostly visionary or impractical, because they fail to provide for all the circumstances.

Alternative Schemes.

These include—1. Deep-water Wharves at or near Gravesend. 2. Extensions of Deep-water Docks similar to Tilbury. 3. Jetties along the river front extending into the deep channel. 4. Dockisation of parts of the river by dams and locks, and the construction of cuts across bends of the river. 5. Formation of a Deep-water Basin below Gravesend by training wall.

None of these have met with much support or approval, because they are only partial remedies, besides being very costly or impracticable.

The objections to these proposals may be summarised as follows :—

(1.) Deep-water Wharves.

Estimated to cost £1,000,000, with 1,000 yards of deep frontage berths ; situation above Greenhithe on the south bank of the river. This scheme was originated in 1905, and is now revived and described as per newspaper paragraph as follows :—

NEW DEEP-WATER DOCKS ON THE THAMES.

A big scheme is now under way for constructing large deep-water wharves on the Thames, and as a considerable number of shipping people, as well as other firms (including one with a capital of 3 millions), are stated to be interested in the project, the idea is likely to take practical shape. A preliminary syndicate—the London Ocean Wharf and Land Development Syndicate, Limited—has been registered, with a capital of £13,750, in 250 "A" shares of £50 each, and 25,000 "B" shares of 1s. each. Later on a company is to be formed with a capital of £400,000, of which more than half is said to have been promised.

A Frontage of 3,600 Feet.

The idea of those who are promoting the scheme is to utilise the deep water of the river at a point west of Greenwich and opposite Purfleet, the south side having been chosen because the deepest water is to be found there. The wharfage will have a frontage to the river of 3,600 feet, and a width of 59 feet ; and, with a little dredging, it is expected to attain a minimum depth of water of 30 feet at lowest tide.

One of the features of the scheme is that there will be direct connection between the Wharf and the South Eastern and Chatham Railway. Some six years ago a Bill was promoted in Parliament for the creation of the Purfleet and Gravesend Tunnel. That Bill was dropped because of the fear of insufficient traffic on the south side of the river. In consequence, however, of the prospects of traffic from the proposed new wharves, the tunnel project is now being revived by a number of gentlemen with large interests in the river.

Extensive Accommodation.

Further, the wharf will have an in-shore side, forming, as the *Shipping Gazette* puts it, a large pond or canal some 200 feet wide and some 30 acres in extent. Barges will be able to come and

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go at all states of the tide for the purpose of loading or discharging. Again, storage considerations have also been taken into account, and the wharf is to be provided with five double-floored transport sheds. Four lines of railway will run along the wharf, and extensive sidings are to be provided for railway waggons.

A striking point in the scheme is that no ship's dues will be charged. Vessels will not be called upon to pay the 1s. 6d. per ton which they are charged on entering the Docks. The promoters, it is said, will be satisfied with stevedoring charges on the goods which the vessels tranship. In this way, it is argued, the Thames will be helped to retain its transhipment trade. As a fact, the syndicate does not base its greatest expectations of profit upon the shipping. It expects to derive the bulk of its dividend from the increased value of the estate of nearly 300 acres adjacent to the wharf which it proposes to acquire, and which, it is expected, will be snapped up by manufacturers and others. Indeed, it is said that enquiries for land have already come in—one for 50 acres was received on Friday morning.

A London Antwerp.

The promoters assert that they are anxious to do for London what has been done for Antwerp. "Antwerp," a *Leader* representative was told on Saturday, "proposes to increase her deep-water quays at a greater ratio than she is increasing her dock quays. It is an anomalous thing that at Antwerp the great liners use the river wharves, and the miscellaneous traders the docks, whereas in London the great liners use the docks, and the miscellaneous traders the river."

The promoters have already obtained a license from the Thames Conservancy for their scheme, and the license has been confirmed by the Board of Trade.

The objections to this proposal are: The situation is on the wrong side of the river. It is too far from the London markets involving slow and costly barging or railway journey, the great railways are all on the north side of the river. The extra expenses on landing, &c., to pay interest on the capital will neutralise any benefit from saving navigation of the river, and from the engineering point of view the wharves will be costly to keep clear of silt and mud.

(2.) Extensions of Deep-water Docks.

Similar to Tilbury. The cost of docks necessitates a heavy toll on shipping using them. The docks will be too far from London and involve costly barging or railway carriage, besides delay. The capital for these docks could only be raised by a Government guarantee.

(3.) Jetties Along the River Front.

Advocated by Sir F. Dixon-Hartland. In this case the cost does not constitute an objection, but the difficulties of mooring and discharging or loading in the tideway with large steamers rising and falling with the tide has been found in practice almost prohibitive. But the chief objection is the obstruction offered to the navigable channel, the tide and loss of scour necessary in a tidal river.

(4.) Dockisation of Parts of the River.

Employing dams and locks and cuts. The most prominent of these is a proposal to dam the river below Blackwall and widen the West India Docks to form a cut or straight channel for the river, building dams at Limehouse and at Blackwall, so that the bend at the Isle of Dogs will become a great dock, while the tidal river will run in the new channel. In this scheme, cost is manifestly prohibitive. Two dams with locks, and a new river channel, 1 mile long by 600 feet wide, will cost at least £13,000,000

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But if constructed, it is obvious that the standing difficulties of navigation, depth of river, tidal delays, and other disabilities will not be amended and will still have to be dealt with in other ways, besides which the heavy capital expenditure will cause a heavy toll on the shipping.

(5.) Formation of a Deep-water Basin Below Gravesend.

This is not an engineer's proposal, the risk of silting up is too great for any engineer to undertake the responsibility. But, apart from this, the basin will be far from the London markets, the great railway systems, and in too exposed a situation to attract shipping. The cost, too, is very heavy, and will need heavy dues to meet it.

Proposals to improve the navigation of the river by dams with locks and weirs have been made as far back as 1857, but none of these proposals contemplated a dam below Woolwich or Blackwall, but it is obvious that, though by such means the river above the proposed dam could be held up, yet below the dam the difficulties of navigation—which since 1857 have greatly increased—would remain unimproved.

In 1859 a paper was read by Mr. W. R. Browne, M.Inst.C.E., at the Institution of Civil Engineers (Vol. 66), on "The Relative Values of Tidal and Upland Waters," which was followed by a long discussion by most of the eminent engineers of the day. In this paper the exclusion of tidal water was advocated, and the position affirmed that only or chiefly the upland water is effective in keeping open a river channel; the tidal water merely oscillating up and down and depositing as much silt on the flood as it removed on the ebb.

Dockisation of Rivers.

Mr. H. Robinson, M.Inst.C.E., also read a paper (Inst. C.E., Vol. 15, p. 205), advocating a dam and range of locks across the Thames at London Bridge to hold up the upper river to 1 foot below H.W.S.T. In both instances there was much division of opinion among engineers, some advocating and others opposing.

In 1755, Smeaton proposed the dockisation of the River Clyde as a means of providing a sufficient depth of water for the increasing trade of the Port of Glasgow. His plan was rejected, and the Clyde Trustees have since expended £7,430,000 in dredging and improving the river to a low-water depth of 20 feet, and now spend annually a large sum in maintaining this depth. Thos. Howard proposed the dockisation of the Avon at Avonmouth in 1877, to provide sufficient depth of water for vessels passing to the Bristol Docks up and down the Avon, there being a rise and fall of tide in the Severn of over 40 feet. His proposal was not adopted because the extraordinary range of tide would have left the entrance unapproachable at low water, causing delay in the Severn Channel.

Messrs. L. Murray and W. C. Mylne recommended the dockisation of the River Wear in 1846, but this was not carried out.

The Czar of Russia recently approved a great dockisation project, consisting of a dam with locks and sluices across the Straits of Kertch, in the Black Sea, to raise the level of the Sea of Azov for the purpose of facilitating navigation to the Port of Taganrog and the River Don. The Sea of Azov will then become a fresh-water lake,

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THE THAMES BELOW TOWER BRIDGE.

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with an increased depth of water (14½ feet) and an area of 10,000 square miles. The dam will be 9 miles long, and it is estimated to cost £5,000,000. This project will no doubt be retarded by the result of the recent war.

Canalisation.

In upland and non-tidal rivers, damming or canalisation as a means of obtaining a permanent navigable depth of water is very common. Most of the great rivers of the Continent are so dealt with, and on the Thames itself there are 32 dams or weirs with locks between London and Oxford, so that the proposal to construct another one only differs from those already in existence in the fact that it will be in the lower tidal part of the river.

A similar dam is now nearly completed across the Charles River, Boston, U.S.A., which, being of great interest as a parallel to that of the Thames at Gravesend, is fully discussed in the following pages. (p. 61.)

The Barrage Committee.

In the following studies and Reports the writers have considered impartially all the evidence brought to bear on the subject alike by sympathisers and objectors, whether for or against the project. Nothing that has been advanced and brought to their notice in the very numerous newspaper paragraphs, statements, or speeches of public men, or objections urged by speakers at public meetings, has been disregarded, though in some instances these have been of very doubtful or remote bearing on the subject.

The Booklets issued by the Thames Barrage Committee in 1904 and 1905, entitled "The Great Thames Barrage," briefly and concisely explained the proposal, and indicated an outline of the advantages and objections so far as they could be foreseen, giving such replies as in a brief space could be made to such objections. There were, however, in course of public discussion some other objections urged, most of which, being effectively explained, dropped out of the discussion, and, as might be expected, the objections concentrated eventually upon two or three points, which, although replied to, could not, from the nature of the case, be effectively disposed of in a few paragraphs.

In the minds of the public, these latter objections, there is no doubt, still stand as not fully answered, and their efficient examination in themselves constitutes a sufficient ground for the enquiry undertaken in the following pages.

This applies more especially to the questions dealt with in Sections XI., XIV. and XV.

In addition to objections, it has been found that river officials, captains of vessels, pilots and others, who might be expected to have an intimate knowledge of the river and its *régime*, have displayed an extraordinary lack of technical knowledge. Their acquaintance seems in most cases to have been confined to a practical knowledge of its navigation, currents, and tides, the result being that they have formed the most erroneous ideas as to the effects that would follow the proposed damming of the river, some of the assertions bordering closely on the ridiculous.

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This may be partly due to a lack of literature on the Thames; not that there are no writings on the subject, but that they deal only with its superficial, artistic, trading, and similar aspects. The most valuable papers being those contained in the Proceedings of the Institution of Civil Engineers. Such other technical information as is available is to be found in the Reports of Royal Commissions; the L.C.C., &c., and is therefore more or less scattered and disconnected. This deficiency in technology of the river is to a great extent filled by the writers herein.

The Report of the Royal Commission on the Port of London, 1902, while presenting a vast amount of trade, navigation and general information, deals but slightly with the questions of the *régime*, geology, sanitary condition of the river, and kindred technical subjects—the marsh lands, drainage, river walls and so on; so that this absence of official investigation is in itself alone a sufficient reason for the preparation and publication of this work, and, whatever may be the result, there can be no two opinions as to the need for enquiry, in order that any course which may be determined on by the Authority of Parliament may be taken after full consideration of all the phases of the question, and not merely one dictated by vested interests, however great their standing and authority.

Summary of Reports.

Briefly stated the general conclusion to be drawn from the following Reports is that the construction of a Barrage at Gravesend, or thereabouts, is quite practicable, and, subject to certain reservations and additional works, ought to be given effect to.

In an undertaking of such magnitude it is inevitable that some interests must be interfered with; many greatly benefited, a few depreciated or driven to adopt changes of policy or action in the conduct of their business; but there can be no question as to the public benefit, which must be of enormous and therefore paramount importance.

Conclusions.

Reviewing these various Sections, it is manifest that there are no insuperable difficulties, and such difficulties as do exist can be met and provided for effectively with a moderate outlay; moderate, that is, when considered in connection with the great public benefits to be derived from the execution of a single work, having such far-reaching results. The cost of a Barrage and its adjuncts as estimated (5¼ millions) is, after all, a mere trifle in comparison with the monetary, trading and public advantages to be gained, and the removal from the financial horizon of vast expenditure otherwise considered as inevitable.

Of the difficulties considered the most important are the questions of drainage and percolation, referred to in Sections XV. and XVI. That these can be effectively dealt with is obvious, but the enquiries so far instituted—while sufficient for a reasonable and reliable estimate—are not exhaustive, but must form the subject of a full examination, so that the best and most economical mode of treating each area may be carefully considered, and a general scheme adopted embodying these as a whole. The present plan of discharging the effluents at Barking and Crossness will have to be modified, so as to increase the area of distribution, instead of concentrating the discharge at two

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points. There is also the further question of the expediency (the necessity is not proved) of providing marginal drains to carry all effluents and drainage to a point below the Dam. This was proposed many years ago, and only rejected on account of the cost, but it is possible, in view of Mr. Dibdin's proposal to adopt the bacterial treatment for the London sewage, that the effluents may be so greatly improved that these marginal drains will be quite unnecessary. Of the other difficulties propounded from time to time little need be said, the extent to which they apply and the means of avoiding them are clearly and fully stated; and it may be said that even fuller and more detailed examination of them is likely to confirm rather than weaken the conclusions arrived at.

THE WORK OF THE BARRAGE COMMITTEE has consisted in the publication and distribution of descriptive booklets, the presentation of memorials to the various authorities interested, as also to the dock, shipping, wharf, lightering and other river-side interests. Many resolutions in favour of the project have been passed by important local and general authorities, copies of which are appended below. A joint deputation of the City Corporation and the Thames Conservancy Board waited upon the President of the Board of Trade in 1904 to urge the desirability of an expert enquiry into the matter. Many members of the late House of Commons interested themselves in the subject also in the endeavour to obtain this enquiry.

PUBLIC LECTURES, fully illustrated, have also been given by the late Chairman, Sir Thomas Brooke-Hitching, and by Mr. T. W. Barber, M.I.C.E., the Engineer, and by Mr. Casey, M.I.N.A., at Bermondsey, Woolwich, Northfleet, Grays, the Cannon Street Hotel, &c., at all of which unanimous resolutions in favour of an enquiry were passed and forwarded to the Board of Trade.

More recently, at the Mansion House, a meeting was called by the Lord Mayor, who presided, to consider the proposal, and was addressed by the late Chairman, Sir Thomas Brooke-Hitching; Sir Douglas Fox, past President M.Inst.C.E.; Mr. T. Hennell, M.I.C.E.; Mr. W. J. Dibdin, F.I.C., F.C.S., &c., formerly Chief Chemist to the Metropolitan Board of Works and L.C.C.; Mr. T. W. Barber, M.Inst.C.E.; Mr. Arnold F. Hills, Chairman of the London Steamboat Company and of the Thames Ironworks and Shipbuilding Company, and others; but the resolution to recommend an enquiry was lost owing to the hostility of a large section of dock sympathisers, who, apparently, consider that the scheme will injure their interests. Whether, in fact, this is or is not the case will be apparent from the investigation made in Section XXIV.

The Committee feel that the subject has suffered from the want of an official, or, at least, an exhaustive study or enquiry, which has left it open to hostile critics to make assertions based upon mere opinions, unsupported by facts and reasoned argument; and therefore publish the following studies and Reports, the work of the most capable men of the day, dealing fully and impartially with every phase of the subject and every difficulty or objection that has been put forward in such a manner as leaves nothing to mere opinion or prejudice, and where every weight is given to such facts and evidence as tell against the proposal, and the means are suggested and examined for coping with such facts and evidence.

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RESOLUTIONS PASSED BY PUBLIC BODIES AND AT PUBLIC MEETINGS IN FAVOUR OF AN ENQUIRY BY THE BOARD OF TRADE OR OTHERWISE INTO THE PRACTICABILITY OF THE THAMES BARRAGE PROPOSAL.

PUBLIC MEETING AT THE DRILL HALL, BERMONDSEY, NOVEMBER 17TH, 1904.

"To the Right Hon. THE PRESIDENT OF THE BOARD OF TRADE.

"SIR,

"I have the honour to transmit to you the following resolution which was passed at a large and influential meeting, held at the Drill Hall, Bermondsey, on Thursday, the 17th instant, Colonel Samuel B. Bevington, V.D., J.P., ex-Mayor of Bermondsey, in the chair.

"This meeting was attended by the Mayor, many of the Aldermen and Councillors of the Metropolitan Borough of Bermondsey, representatives of the Surrey Commercial Docks, of the Wharfingers, Steamboat proprietors, Bargeowners, watermen, stevedores and dock labourers.

"After a paper read by Sir Thos. Brooke-Hitching, L.C.C., illustrated by lantern slides, shown by Mr. T. W. Barber, M.Inst.C.E., the designer of the Thames Barrage, the following resolution was proposed by Sir Thos. Brooke-Hitching, L.C.C., seconded by the Mayor of Bermondsey (Councillor Augustus Shand) and carried unanimously, and ordered to be forwarded to H.M. Government.

"I have the honour to be, Sir,

"Your obedient servant,

"S. B. BEVINGTON,

"*Chairman.*

"RESOLUTION.

"'That this meeting respectfully calls upon H.M. Government to institute an enquiry by Commission or otherwise as to the expediency or otherwise and practicability of erecting a Barrage with locks across the River Thames at Gravesend, as an alternative to the proposal to dredge the river for the purpose of navigation.'"

PUBLIC MEETING AT GRAYS, NEAR TILBURY, ESSEX, MARCH 18TH, 1905.

"The Chairman, Mr. Goodman, then moved as follows:—

"'That this meeting is of opinion that a Government enquiry or a Royal Commission is desirable as to the merits or otherwise of the Great Thames Barrage Scheme, before the Government is in any way committed to other legislation in respect to the improvement of the navigation of the Thames.'"

"This was seconded by Mr. Bullock and carried unanimously."

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"COURT HOUSE, GRAVESEND,

"*January 21st*, 1905.

"SIR,

"THAMES HARBOUR BILL, 1905.

"I am directed by the Northfleet Urban District Council to draw your attention to the above Bill which is being promoted in Parliament by the Thames Barrage Committee, and also to the various other schemes for the improvement of the Port of London which are now under consideration by the Legislature and the general public.

"The Northfleet Council recognising the vital importance to the welfare and prosperity of the country generally (and in particular of their own district which is situated within the Port of London) of an improved harbour and increased facilities for commerce in the Thames, respectfully suggest that before the subject is submitted to the final arbitrament of Parliament an exhaustive enquiry into the merits of the different schemes (including the construction of a dam across the Thames at Gravesend) should be made by a Commission specially appointed for the purpose.

"I have the honour to be, Sir,

"Your obedient servant,

"CHAS. E. HATTEN,

"*Clerk.*

"The Right Honourable A. J. BALFOUR, M.P.,
"First Lord of the Treasury,
"Downing Street, Westminster, S.W."

"COURT HOUSE, GRAVESEND,

"*December 2nd*, 1904.

"SIR,

"I am directed by Mr. Shotton, the Chairman of the Northfleet Urban District Council, to inform you that at the invitation of the Council, a lecture on the Thames Barrage Scheme was delivered by Sir Thomas Brooke-Hitching, and explanations were given by Mr. Barber, M.Inst.C.E., at a meeting of owners of riverside properties and barges and others, invited by public advertisement, and held at the Factory Hall, Northfleet, on Wednesday, the 30th ulto, of which Mr. Shotton was the Chairman; that at the close of the lecture and of the explanations it was moved by Mr. C. Cobham, F.S.I., and seconded by Councillor Milton, and resolved with only one dissentient, "'That the Prime Minister be respectfully requested to institute a public enquiry into the merits of the Barrage Scheme.'"

"By the direction of the Chairman I have the honour to request accordingly.

"I am to add that the Hall, which is capable of seating upwards of 600 persons, was practically full of men.

"I have the honour to be, Sir,

"Your obedient servant,

"CHAS. E. HATTEN,

"*Town Clerk.*

"Right Honourable A. J. BALFOUR, M.P.,
"First Lord of the Treasury."

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METROPOLITAN BOROUGH OF WOOLWICH.

"TOWN HALL, WOOLWICH,

"*July 4th*, 1905.

"DEAR SIR,

"My Council have had under their consideration your letter of May 25th last, in reference to the proposed Thames Barrage, and have instructed me to inform you in reply that, whilst not expressing any opinion upon the merits of the proposal, they think that it is one which deserves full investigation, and have accordingly communicated with the Board of Trade urging the importance of instituting an expert enquiry into the matter before further legislation upon the Port of London is undertaken.

"Yours faithfully,

"ARTHUR B. BRYCESON,

"*Town Clerk.*

"T. W. BARBER, Esq.,
"17 & 18, Tothill Street, Westminster."

BOROUGH OF SOUTHWARK.

"TOWN HALL, WALWORTH ROAD, S.E.,

"*June 23rd*, 1904.

"DEAR SIRS,

"THAMES BARRAGE SCHEME.

"The Borough Council at their meeting last evening had before them your circular letter with regard to the Thames Barrage Scheme.

"After giving the matter their careful consideration, the Borough Council decided to petition Parliament to delay the consideration of the Port of London Bill in order that full enquiry may be made into the Thames Barrage Scheme, and to request the members of Parliament for the Borough to support the petition.

"Yours faithfully,

"J. A. JOHNSON,

"*Town Clerk.*

"Sir THOS. BROOKE-HITCHING, L.C.C.,
"W. H. GRENFELL, Esq., M.P.,
11, Portland Place, W."

METROPOLITAN BOROUGH OF HACKNEY.

"TOWN HALL, HACKNEY, N.E.,

"*February 2nd*, 1905.

"CERTIFIED EXTRACT from the Minutes of a Meeting of the Council of the Metropolitan Borough of Hackney, held on Thursday, January 26th, 1905.

"SECTION 'F' OF REPORT OF WORKS AND GENERAL PURPOSES COMMITTEE.

"'Letter from the Thames Barrage Committee with reference to the Thames Harbour Bill, 1905, urging that before any legislative steps are taken by Parliament,

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a Commission should be appointed to hold an enquiry into the whole question of the method of dealing with the Port of London, including the Barrage, and asking this Council to pass a resolution advocating the appointment of such a Commission.

"'Recommending that this Council do support the proposal for that before any legislative action is taken by Parliament in relation to the subject of the Port of London, a Commission should be appointed to enquire into the whole question of methods of dealing with the Port, including also the scheme for a Barrage.

"'It was resolved, on the motion of Councillor G. A. Hasemer, "That Section 'F' of the Report be adopted."'

"CERTIFIED to be a true Extract from the Minutes of the Meeting of the Hackney Metropolitan Borough Council, held on January 26th, 1905.

"W. A. WILLIAMS,

"*Town Clerk.*"

METROPOLITAN BOROUGH OF WANDSWORTH.

"COUNCIL HOUSE, WANDSWORTH, S.W.,

"*June 9th*, 1905.

"SIR,

"Referring to your circular on the subject of the Thames Barrage Scheme, I beg to inform you that this Council has decided to present a petition to the House of Commons against the Port of London Bill, and in favour of a public enquiry with reference to the proposed Barrage Scheme.

"I am, Sir,

"Your obedient servant,

"HENRY GEORGE HILLS.

"Sir THOS. BROOKE-HITCHING, L.C.C.,
"11, Portland Place, W."

THAMES BARRAGE.

THAMES CONSERVANCY BOARD.

"*May 16th*, 1904.

"THE PROPOSED BARRAGE OF THE THAMES.

"The Chairman presented a Report from the Lower River and General Purposes Committee on the subject of a letter from the Town Clerk of the City inviting the Conservators to join the Special Port of London Committee in a deputation to the Board of Trade in favour of that Department's holding an enquiry into the Barrage Scheme. The resolution was carried by a large majority."

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CORPORATION OF LONDON.

"*May 9th*, 1904.

"BARRAGE OF THE THAMES.

"The Special Committee of the Corporation on the Port of London report that the advantages claimed for the Barrage Scheme were so many that the Committee, while unable to express any opinion as to its merits at the present time, thought that its practicability should be fully and impartially enquired into, and that the Board of Trade should be invited to hold a public enquiry on the subject. This recommendation has been adopted by the Corporation, who are communicating with other public bodies on the matter."

CITY CORPORATION.

REPORT OF THE PORT OF LONDON COMMITTEE.

"*May 16th*, 1905.

"THE THAMES BARRAGE SCHEME.

"The Committee recommend the Council to make a representation to the Government in favour of the appointment of a Commission or Departmental Committee to enquire into the Barrage Scheme."

In response to the generally expressed desire that expert testimony of the highest character should be obtained in confirmation of the statements and opinions advanced by the Engineer, Mr. T. W. Barber, M.Inst.C.E., in his pamphlet entitled "The Great Thames Barrage," the following important confirmatory letters were received from Sir Douglas Fox, Past President Inst.C.E., and Mr. W. J. Dibdin, F.I.C., F.C.S., and were transmitted to the Board of Trade:—

ON THE ENGINEERING QUESTION.

"28, VICTORIA STREET, WESTMINSTER, S.W.,

"THE SECRETARY, "*April 6th*, 1905.

"Harbour Department, Board of Trade.

"SIR,

"THAMES BARRAGE.

"THAMES HARBOUR BILL, 1905.

"I have had under consideration, at the request of the Promoting Committee of the above Bill, the proposal to place a dam or Barrage with locks and sluices across the Thames at Gravesend. I think this presents very considerable advantages over other schemes for improving the navigation of the Thames, and that certainly the plan is one that ought to be carefully considered before Parliament comes to a decision as to future legislation in connection with the Port of London.

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"The Barrage and locks, as contemplated in the Bill (as deposited for the present Session), which would have to be carried out without undue interference with the drainage and the navigation, will, of course, form an engineering work of importance, but, so far as I can foresee, without further investigation, there should be no practical difficulties therein which cannot be readily overcome. A final decision as to the best course to be adopted can, however, in my opinion, only be arrived at after a careful and detailed examination into all the circumstances of the case.

"Having had for many years experience of the riparian conditions of the Thames, I have serious doubts as to the practicability of the alternative proposal to dredge the river, and I suggest that this plan should be considered at the same time as the Barrage proposal.

"I am, Sir,

"Yours faithfully,

"(Signed) DOUGLAS FOX."

ON THE SANITARY QUESTION.

"2, EDINBURGH MANSIONS,

"HOWICK PLACE,

"W. J. DIBDIN, F.I.C., F.C.S., F.R.M.S., &c. "VICTORIA STREET,

"Analytical and Consulting Chemist. "WESTMINSTER,

"*April 9th*, 1905.

"THE SECRETARY,

"The Board of Trade.

"SIR,

"THAMES BARRAGE SCHEME.

"In accordance with a request received from Mr. T. W. Barber, M.Inst.C.E., I have the honour to submit the following observations upon the probable effect, from a sanitary point of view of the above proposed scheme, if carried out, on the condition of the River Thames.

"I may premise the following remarks by stating that my professional experience of the River Thames dates back to 1876, when I was acting as assistant to the late Mr. T. W. Keates, Consulting Chemist to the Metropolitan Board of Works, when I was engaged in connection with an Enquiry as to the condition of the river and its mud-banks, and the subsequent arbitration, known as the 'Mud Enquiry.' This was followed by a further enquiry in reference to the 'Princess Alice' disaster at Woolwich, and later by very exhaustive enquiries in connection with Lord Bramwell's Royal Commission as to the effect of the discharge of the London sewage.

"In 1882 I succeeded Mr. Keates in the position of Chemist to the Metropolitan Board of Works, and continued to hold that post under the London County Council until 1897, when I resigned in order to leave myself at liberty to respond to the many invitations to undertake private practice.

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"In 1884 I commenced a series of experiments as to the most advisable means of treating the sewage of London before its discharge into the Thames, and in connection therewith devised the process then adopted and now in use for that purpose, and supervised the work until the time of my resignation. In connection with this work I carried out the original experiments on the bacterial treatment of sewage, and supervised and successfully brought into use the one acre bacteria bed at Barking Creek, which was the forerunner of all the now well-known systems of the bacterial treatment of sewage. In order to ascertain the effect of the various operations thus carried out, I made systematic examinations of the river from above London to points below the Nore, so as to cover the whole length which could be affected by the operations thus carried on at the outfalls, and by the discharge of the sludge therefrom into the estuary below the Nore.

"The results of these numerous researches and enquiries are embodied in official reports; in my evidence before various Royal Commissions; and are succinctly described in my work on 'The Purification of Sewage and Water,' now in its third edition.

"From over 20 years' intimate experience of the river in all seasons and at all tidal variations, I am clearly of opinion that the proposed scheme of placing a dam at Gravesend, and thus converting the river above that point into a fresh-water lake, would effect an enormous improvement in every way. I am not, however, quite clear that the present method of obtaining and discharging the effluent from the works at Barking Creek and Crossness would under the new circumstances be the best, and it must be understood that pending further information on the point I think it should be reserved for the present. But I am perfectly clear in my opinion that when the improvements in the effluent obtained from the London sewage, which have been demonstrated by myself in my former official capacity as being desirable and easily obtainable, and most strongly recommended by my successor, Dr. Clowes, are effected, there will be no shadow of doubt whatever as to the enormous improvement which will be made in the character of the river. For instance, at present fish life is practically absent below Hammersmith. Under special circumstances a few fish may be found lower down, but in summer especially nothing of importance will be found between Hammersmith and Gravesend. Just as a few fish under flood conditions, &c., may get below Hammersmith, so at high water, spring tides, may whitebait be caught at Erith, or even higher, but this is not the normal condition of things. Under the proposed condition of the river, I see no reason whatever why fish life should not be abundant in all parts of the river, and this simple physiological test indicates more definitely than volumes of assertions that the improvement of the water would be of enormous importance in every way.

"I am, Sir,

"Yours faithfully,

"(Signed) W. J. DIBDIN,

"F.I.C., F.C.S., F.R.M.S., &c.,

"*Vice-President of the Society of Public Analysts.*"

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SECTION II.

AUTHORITIES GOVERNING THE RIVER THAMES.

One of the chief anomalies brought prominently to light by the Royal Commission on the Port of London is the existence of quite a range of public authorities with overlapping powers and areas of administration, and as a necessary result numerous drawbacks and difficulties surrounding the transaction of business, navigation, incidence of dues, and so on, which powers, as a rule, in the other large ports are controlled by a single authority, usually a body of Harbour Commissioners, a Port Trust, or Municipal Council.

Complete tables were published by the London County Council in 1900* giving and defining these bodies, their special powers and the areas within which they are exercised, from which the complication and conflict that necessarily arise where numerous jurisdictions meet and overlap can be studied.

The following is a summary of these various authorities and their powers as given in the above Report:—

THE THAMES CONSERVANCY BOARD controls the navigation and maintains order (but not policing), regulates the mooring and placing of vessels, and ballasting. Removes obstructions or dangerous structures, nuisances, and abuses in the river. Regulates the flow and purity of the upper river as far as the boundary of the County of London westward.

Has powers to stop up outlets of sewers, &c., after conviction of owners for causing pollution.

Collects tonnage dues on vessels, entering or clearing, with power to seize and detain on non-payment.

Has powers to fix beacons for navigation purposes. To put down moorings and take tolls for their use.

Has powers to dredge and scour the river and deepen or improve the channel, remove mud or shoals, shorten bends or angles, license dredgers. To dredge for ballast for the supply of vessels, or sell same for general purposes.

Has powers to erect piers or landing places and to lease same, to provide approaches to such piers, &c.

THE WATERMEN'S AND LIGHTERMEN'S COMPANY controls the licensing of watermen and lightermen (who alone as freemen or apprentices of the Company can navigate, work barges or craft or ply for hire), certifies all craft for navigation, and licenses boatmen and ferrymen.

THE TRINITY HOUSE certificates any harbour master appointed by the Thames Conservators, superintends and manages all lighthouses, also all buoys and beacons. Appoints pilots and grants pilotage certificates to masters and mates of vessels.

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* L.C.C. Port of London, Dock Accommodation;
Part II. Authorities of the Port with synopsis of their powers, duties and rights.

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THE CITY CORPORATION is the Port Sanitary Authority for the Port of London, and is required to light the Tower Bridge.

THE DOCK COMPANIES have powers extending from 100 to 300 yards from their entrances, to keep them clear of vessels and control, dredge, and scour the approaches to them within these limits, and no moorings may be fixed within these limits without their consent. These powers are also exercised by the Canals and Railway Docks which open into the river.

THE BOARD OF TRADE is empowered to remove works in tidal waters abandoned or fallen to decay, or works not approved by them.

THE ADMIRALTY has power to remove or prevent obstructions between signal and coastguard stations, and to remove works in tidal waters abandoned or fallen to decay.

THE LONDON COUNTY COUNCIL has power to enforce the Rivers' Pollution Prevention Act within the County of London, and powers to dredge within certain limits near Woolwich Ferry.

THE METROPOLITAN POLICE AUTHORITY is the police authority on the Thames within or adjoining the Metropolitan Police area, and nominally on all docks, inlets, waters, creeks, wharves, quays, and landing places and over all places within 100 yards on either side of the Thames, where it flows through the Metropolitan police area, also to maintain order in passage of vessels where large crowds may assemble.

All the following public bodies have powers to make and maintain one or more piers or landing places, wharves, or jetties :—

London Riverside Fish Market Company.
Greenwich Pier Company.
Southend-on-Sea Corporation.
Metropolitan District Railway Company.
Great Eastern Railway Company.
South Eastern and Chatham and Dover Railway Company.
London Tilbury and Southend Railway Company.
Metropolitan Asylums Board.

The confusion and complications arising from want of co-ordination of areas of jurisdiction is well illustrated in the case of the Thames Conservancy Board, whose various duties and powers are exercised in five different areas for different purposes.

The Thames Conservancy Board is a comparatively new body dating from 1857, but the Trinity House and the Watermen's Company are of very old origin, the latter dating from 1827, but originating in an old Guild dating from the 16th century.

There are also different areas of jurisdiction for the Customs and the Port Sanitary Authority (the City Corporation).

The Royal Commission on the Port of London was unanimous in its condemnation of this multiplication of authorities, and in its Report recommended one authority constituted as follows :—

Page 313.—" We suggest, then, that :—

" (1) The Port Authority should consist of about 40 persons, partly nominated and partly elected.

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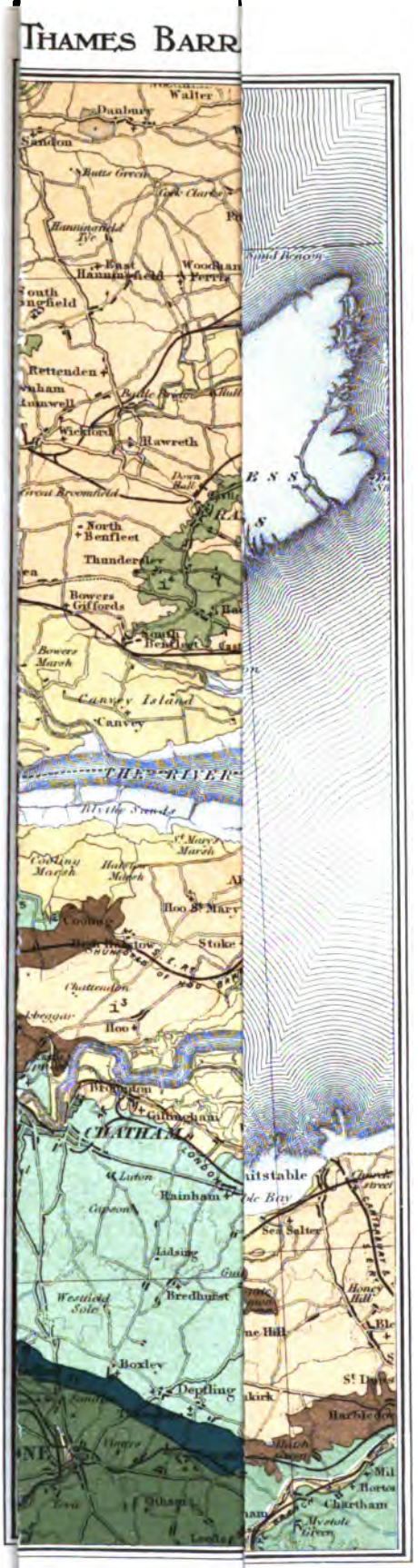

INDEX

Alluvium.	
LOWER EOCENE	Bagshot and Bracklesham Beds
	London Clay
	Lower London Tertiaries (Oldhaven Beds, Woolwich & Reading Beds, Thanet Beds)
UPPER CRETACEOUS	Chalk
	Upper Greensand
	Gault
LOWER CRETACEOUS	Lower Greensand

Neocomian

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" (2) On the assumption that the London County Council and the City Corporation accept the financial responsibilities which we have recommended, the nominated members should be appointed by the following bodies :—

" (*a*) By the London County Council	11	members.
" (*b*) By the City Corporation	3	"
" (*c*) By the Admiralty	1	"
" (*d*) By the Board of Trade	1	"
" (*e*) By the Trinity House	1	"
" (*f*) By the Kent County Council	1	"
" (*g*) By the Essex County Council	1	"
" (*h*) By the London Chamber of Commerce	2	"
" (*i*) By the Governors of the Bank of England from among persons belonging to the mercantile community of London	5	"

" (3) The elected members should be elected by different groups of voters, viz. :—

" (*j*) By the oversea (or ocean) trading shipowners ..	5	members.
" (*k*) By the short sea trading shipowners	2	"
" (*l*) By the wharfingers and owners of private warehouses on the river	3	"
" (*m*) By the owners of lighters, barges, and river craft, including river passenger steamers	2	"
" (*n*) By railway companies connecting with the docks .	2	"

It may be further stated here that the above recommendations have been very generally approved and that, except as to details of the representation of various interests in the proposed Port Trust, very little divergence of view has been shown among the numerous trading and other interests of the Thames. So that all the proposals, Parliamentary or otherwise, put forward since the date of the above Report, have adopted in principle this recommendation.

It is manifest that a single authority may be so constituted as to fulfil effectually all the offices and duties now distributed among many divergent public bodies, and with great advantage to the traders whose daily business brings them into frequent contact with the governing body. Much loss of time, complications of accounts and correspondence will be thereby saved, and the entire conduct of the Port business simplified and rendered more orderly and expeditious.

Most harbours are controlled by a Board of Harbour Commissioners, whose powers are defined by the Special Act and governed generally by the Commissioners Clauses Act, 1846, the Harbours, Docks and Piers Clauses Act, 1847, and other general Acts, and although the Port of London is an unusually extensive Harbour, there seems no reason why a similar body should not control it in a similar way.

The plan has been in use for 60 years, and is found to work harmoniously and to give general satisfaction ; the best reason for this may be said to be the fact that the Clauses Acts above have as yet never been amended, and are still found to work well.

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SECTION III.

GEOLOGICAL CONDITIONS IN THE TIDAL THAMES.

It is necessary, in order to form just conclusions as to any scheme of treatment of the River Thames from an engineering point of view, to carefully consider the geology of the river bottom and marginal lands. The nature of the bottom determines to what extent it may be interfered with in dredging, constructing dams, bridges, or other works, and the marginal lands may be directly and permanently affected by improvements in the river.

Like most rivers, the Thames traverses a variety of formations in which it has cut its channel; but these do not include any rocks or hard strata, consequently the section of channel is fairly regular and no great or sudden changes of width or depth occur.

Technically, it lies in the Lower Eocene strata of the London basin, mostly on the London clay and chalk, which is more or less covered with thin beds of gravels, sand, and alluvial clays. (*See* map.)

The London clay is a thick bed of a peculiar close grey clay of a cheesy consistency, impervious to water and not plastic. It frequently extends in depth to 200 feet or more, and lies above the greensand or chalk formations. The London clay basin extends under the entire estuary of the Thames, where it is covered thinly by sand banks and silt.

It is probably chiefly due to the London clay that the river has maintained for ages its channels with little variation.

The chalk formation, which is below the London clay, forms the bed of the river in patches of considerable extent at Purfleet, Gravesend, Erith, and Grays, where on the adjoining lands chalk pits, lime and cement works are extensively worked.

A chalk bottom to a river must always be a very stable one, and might stand permanently at a considerable angle from the horizontal, but this is not the case with such materials as sand, gravel, clay, or alluvium.

These materials, laid above water in the dry, assume certain angles of repose or stability, of which the alluvium and plastic clays are the flattest and sand and gravel more steep, as follows :—

Dry sand and earth, dry clay	from 21° to 37°
Damp clay	45°
Wet clay..	„ 14° „ 17°
Shingle and gravel	„ 35° „ 48°

but these angles become very much flatter when the materials are immersed in water, because the particles, grains, or pebbles which do not greatly exceed the water in specific gravity are partially in flotation and thus readily moved by any motion in the water. The angles of repose in water then become as follows :—

Sand, earth, and clay	from 3° to 10°
Shingle and gravel	„ 7° „ 15°

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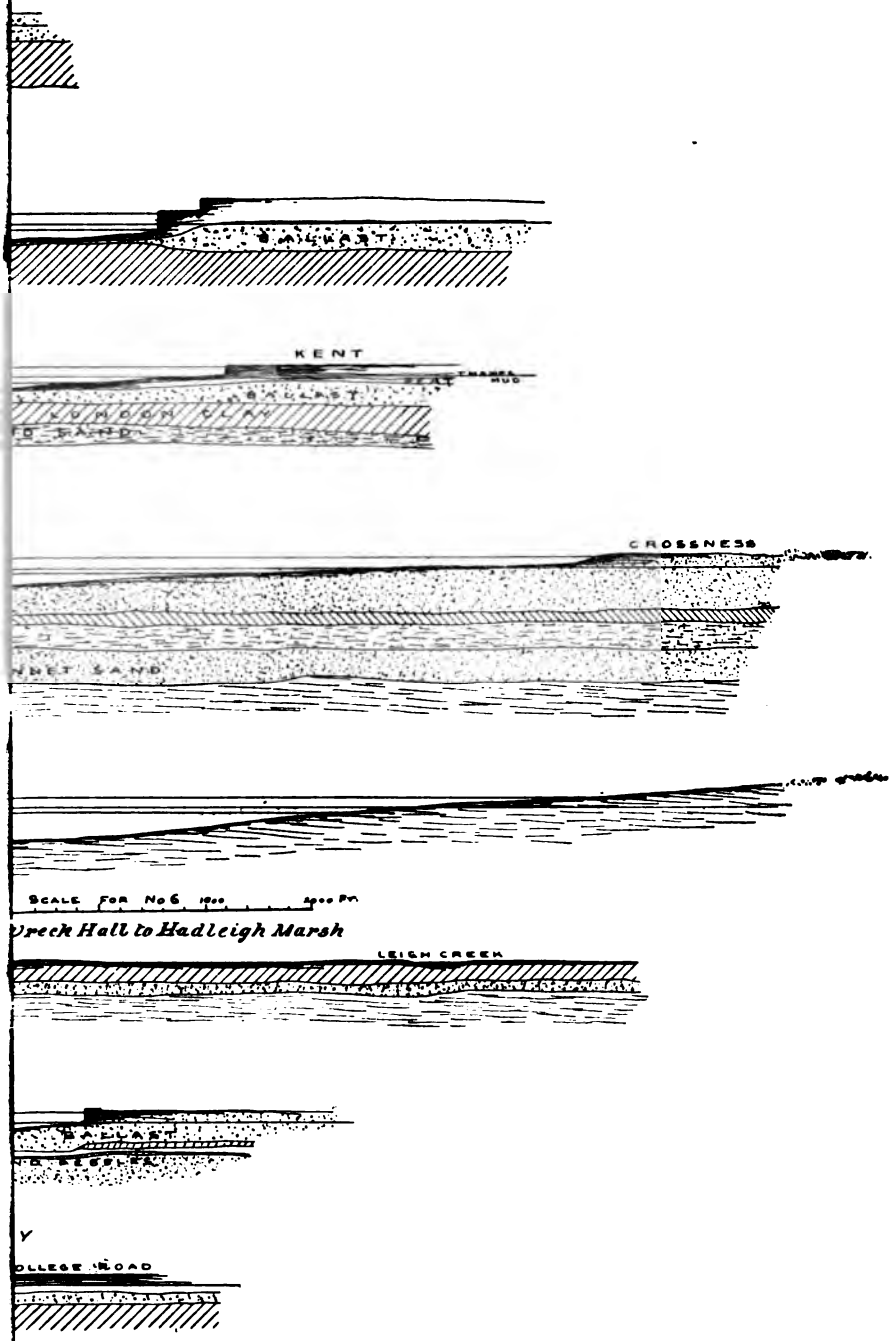

NDERLYING STRATA.

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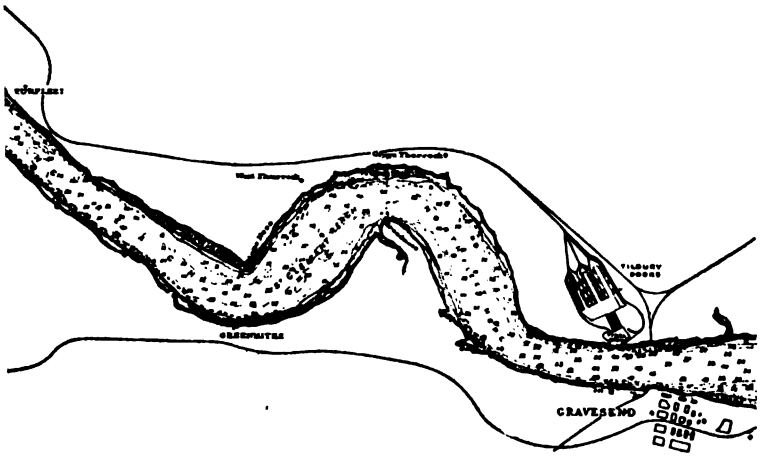
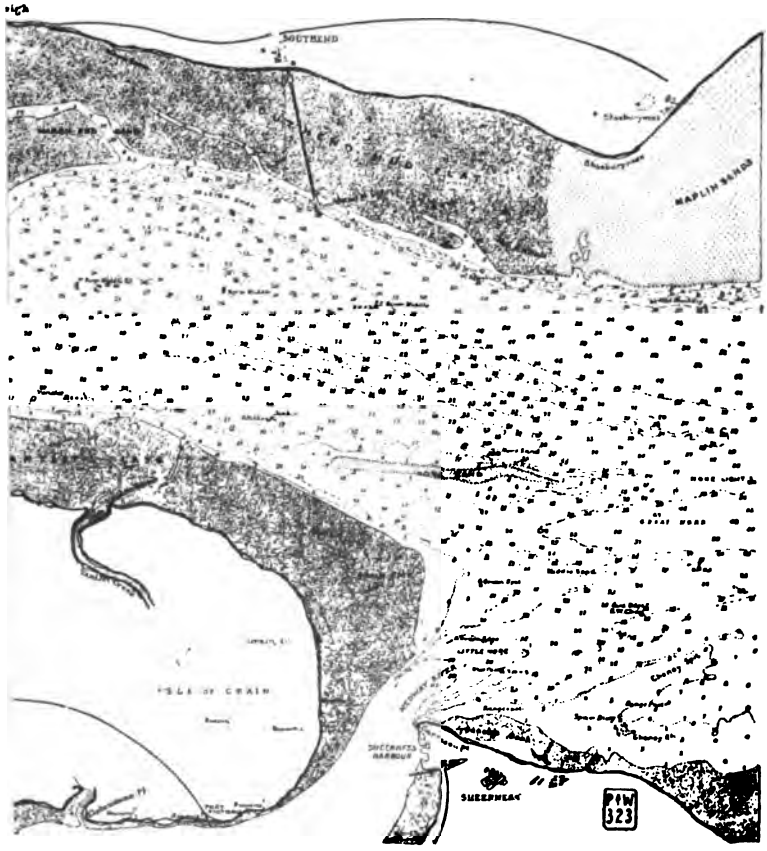


THE THAMES FROM LONDON TO GRAVESEND.



THE THAMES ESTUARY

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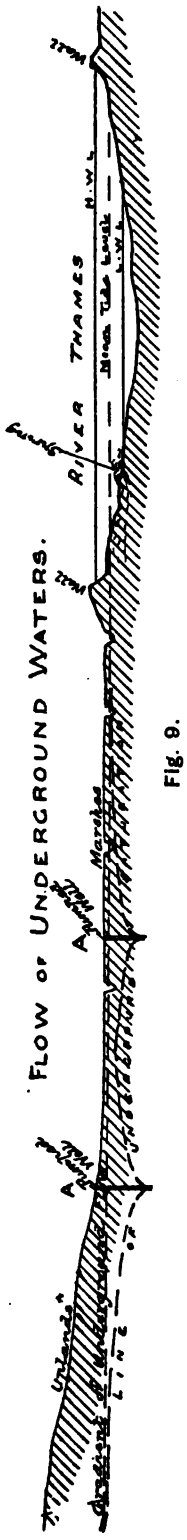

The cross sections of the river bottom (Figs. 1 to 8) show generally that the original surface strata were alluvial, consisting of gravels, sands, loam, and clays, clay shales, and similar materials, easily eroded and mostly pervious.

Through these beds the river has cut its channel, which is covered superficially by mud and gravels washed down from the foreshores to a natural angle of stability, which would be a permanent one if the volume and current of the river always remained constant, but as weather and tidal conditions introduce frequent changes in volume, current and direction, these cause erosion in places and deposit in others, giving rise to the formation of banks and channels, and are the causes of their changes in form and position.

True sections across the bed of the Lower Thames below Woolwich are not available, but only isolated borings and other indications which, from the known outcrops and surface indications, enable the geologist to infer with some degree of accuracy the character of the strata. But above Woolwich we have several true sections, derived from tunnels which have been driven across the bed of the river, and which are given in Figs. 1 to 8. From these it will be seen that the foundation is mainly the London clay and chalk, on which is superposed various thin beds of more or less pervious material and clays, the former undoubtedly saturated with water, except where extensive pumping has kept down the saturation level, or where clay beds interfere with percolation.

In the entire catchment area of the Thames Valley and its branches (*see* map, p. 39), there is undoubtedly a general flow of the underground waters towards the river, for which flow a very slight gradient no doubt suffices. (*See* Fig. 9.)

The waters reach the river chiefly in the form of springs rising in the river bottom and it is manifest that the source of the springs must be at a higher level (as shown) to give the requisite fall to maintain the flow. Where pumping is carried on, as at "A," the surrounding strata are dried down to the pumping level in a conical form—apex downwards—and this may evidently be carried to so great a depth as to cause a flow from the river if the river bed and the intervening strata are permeable.

But a spring discharging into a river bed necessarily keeps its outlet open by its flow of filtered water, the water having deposited its earthy matters in passing down through the superincumbent strata, and therefore will not choke unless the flow should be reversed. Where this takes place from any cause, such as pumping or sinking a deep foundation near a river, the silty water of the river will deposit its silt in the permeable strata through which it passes, and

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this process, if continued, must necessarily in course of time choke the porous mass with silt until the flow is much retarded, or even entirely stopped. Reversal of flow cannot be of frequent occurrence because it must be of artificial origin.

A waterworks filter-bed supplies a good illustration of the deposit of silt. Its bottom is composed of sand on gravel and the filtration is simply the deposit in the interstices of the sand of the silt contained in the unfiltered water. As the process continues, the flow becomes slower and slower until it almost ceases from choking of the sand with deposit. The sand is then removed, and a fresh layer put on, when the filter-bed is again fit to work. Filters are made also which cleanse themselves by reversing the flow for a short time, the foul water thus discharged, which washes out the deposited silt, being run to the sewer.

An investigation of this subject of infiltration and possible percolation from the Thames into the low-lying lands of Kent and Essex is given by Mr. Clayton Beadle in Section XVI.

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SECTION IV.

THE TIDAL WATERS.

A clear understanding of the tidal action in the river, the flow of upland waters and other affluents, and the effects upon these of the configuration of the river, its bottom, foreshores, embankments and of all obstructions that retard or concentrate tidal action, is absolutely necessary as an introduction to the consideration of the best means for improvement and for controlling the river for navigation, sanitation and water supply; the three great uses to which it lends itself in the service of a great population.

In olden times the Thames overflowed its present boundaries East of London on both banks, and spread over the extensive marsh lands which border it on both the Essex and Kent shores. The areas of these were about 30 square miles, and the tidal action in those days would have caused a rise and fall of the waters in these marshes, which, being from 4 to 7 feet below H.W.S.T., would have had a quantity of about 70 million tons of water over them at high water. (*See* map, p. 101.)

The river walls (*see* Sections XVI. and XVII.) have for ages barred out the tides from these low areas, reducing the flood waters, and therefore the volume and current of the river, confining it to its present channel.

THAMES DATA.

The following are the main facts and figures relating to the Tidal River and Estuary as a basis for all calculations :—

Total watershed of the Thames and its tributaries	6034·3 square miles.
Total length with windings	201½ miles.
Number of tributaries	20
Total length of tributaries	464 miles.
Fall of navigable river from Lechlade to London (equals 21 inches per mile)	258 feet.

Annual outflow, 1,176,440,625 tons of water, equivalent to a rainfall of 3½ inches over the whole watershed area, or of 6 inches over the drainage area to Teddington, 3,676 square miles.

Average rainfall, 24 inches per annum, equal to 8,030,597,142 tons.

Average outflow, therefore, from one-fourth to one-seventh of the rainfall.

TOTAL QUANTITIES OF TIDAL WATER, THAT IS FROM H.W. TO L.W.

	Mean Range.	Tons.
London Bridge to Sheerness (43 miles)	15 ft.	142,533,482
London Bridge to Teddington (20 miles)	10 ft.	14,732,143
Gravesend to Sheerness (16 miles)	15 ft.	141,428,571
London Bridge to Gravesend (28 miles)	15 ft.	92,812,500

Mean velocity of current, 2 miles per hour.

Velocity of the first of the flood above bridge, 1¾ to 2 miles per hour.

Velocity of the last of the ebb above bridge, from 2¼ to 3⅓ miles per hour.

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Present Range of Tides.

At Gravesend the extreme range is 24 feet 6 inches (on October 18th, 1841, it was 25 feet 6 inches, with N.N.W. light airs and pressure; neaps rise 12 feet, springs 19 feet

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THE TIDAL WATER travels up and down the river about 13 miles (more or less according to the flow of upland water), but the tidal wave travels the entire length of the river to Tedding-

Fig. 10.

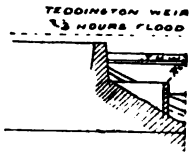


Fig. 11.

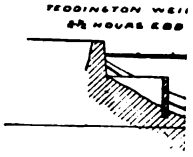


Fig. 12.

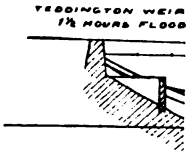
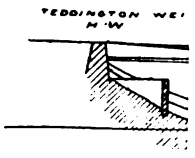


Fig. 13.



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Present Range of Tides.

At Gravesend the extreme range is 24 feet 6 inches (on October 18th, 1841, it was 25 feet 6 inches, with a N.N.W. gale); ordinary neaps rise 14 feet, springs 17 feet

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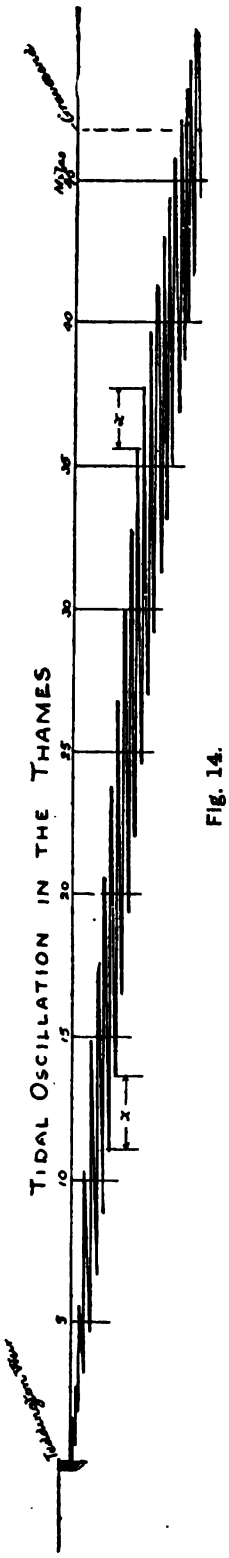

Fig. 14.

THE TIDAL WATER travels up and down the river about 13 miles (more or less according to the flow of upland water), but the tidal wave travels the entire length of the river to Teddington (46 miles from Gravesend) at each tide.

THE OSCILLATION OF THE TIDAL WATER is shown graphically in Fig. 14. The seaward gain (x) at each tide varies with the season of the year, being very small in summer and greater in winter. It represents, in fact, the amount of the upland flow.

It has been proved repeatedly that it takes from 25 to 70 days for the water flowing over Teddington Weir to reach the North Sea by this zig-zagging process.

THE CURRENT flows most swiftly in the middle half of the river and on the outer half round the bends, and varies in speed somewhat in different places. It also runs at greatest speed at about one-third the depth below the surface, and at the bottom the current is generally less than half the speed of that at the surface. (*See* diagrams, p. 69.)

FRESH AND SALT WATER.—There is, of course, a blending of the fresh water with the sea water, which latter is, by the tidal oscillation, carried up from the estuary and distributed up nearly the entire length of the tidal river.

In dry summer weather salt water can be detected nearly up to Teddington. In wet weather it is driven further down by the increased upland flow.

But the salt water, being of greater specific gravity than fresh water, is chiefly at the bottom and pushes up under the fresh water. Admiral Belcher stated that in 1854 it was the practice for war vessels to fill their water casks from the surface water at Woolwich during the first half of the ebb, but they had to be careful not to sink the suction hose more than 2 feet below the surface, or they drew salt water. (*See* diagram, p. 68.)

SPRING WATER AND SURFACE WATER.—There is known to be a large influx of spring water in various places in the bed of the river, which is the surplus of the London clay basin. One authority (Mr. Clayton Beadle) estimates it at 50 million gallons per day, but it is highly probable that this is a very low estimate, for nearly all the water which percolates in the Thames watershed must find its way to the river or to pumping wells. Taking Mr. Beadle's percolation figure of 8·42 inches of rainfall per annum, this gives 3,340,000,000 tons of water per annum, or 2,049,600,000 gallons per day (average), nearly all of which, after deducting the quantity pumped from wells, must reach the river. But we have no means of ascertaining the amount of pumping,

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the only records of which are those of the water companies who pump from wells. It is known, however, that from 100 to 200 million gallons per day are pumped in the London area.

SEWAGE EFFLUENTS.—Besides the foregoing sources of upland flow there are very large quantities of sewage effluents discharged into the river chiefly at Crossness and Barking, but these consist mainly of water previously abstracted from the upper river and from wells for water supply to London, &c., and rainfall of the London streets and places where there is no percolation into the soil. The quantity discharged from London sewers after treatment at Barking and Crossness is now 240 million gallons daily, and to this must be added the storm overflows' discharges of storm water and sewage, estimated by Mr. Santo Crimp at 3 per cent. of the total discharge of the sewers (75,000 million gallons annually), that is, 2,250 million gallons per annum. The quantity and effect of these effluents and storm water discharges are fully treated of in Sections VI. and VIII.

UPLAND FLOW.—The flow of the upper river over the weir at Teddington varies very greatly throughout the year, and also in different years. The diagram (Fig. 15) shows the daily flow for the years 1885 and 1893, which may be taken as representative wet and dry years.

The amount abstracted by the water companies for the supply of London varies with the season. Practically all of this water reaches the river again at Barking and Crossness, so that the abstraction of flow affects the part of the river lying between Barking and the intakes at Hampton and Sunbury.

Thus the daily Teddington flow varies in amount on an average year from 1,500,000 cubic yards in August and September to 11,800,000 cubic yards * in January, which is usually the wettest month.

The qualities of the water are considered on p. 33.

UPLAND AND TIDAL RIVER FLOODS.—These are due to entirely different causes. The floods in the upper river, which occasionally attain serious dimensions covering many square miles with flood waters, amounting sometimes to an increased flow of 33 million tons daily, are the result of heavy and continuous rains which run off to the river, and, reaching it in much larger quantities than its gradient will enable it to carry off, overflow over the flat lands bordering it on both sides. The Thames is not peculiar nor remarkable in this respect. Most rivers overflow more or less in the rainy reason. But the problem of flood prevention is a very difficult one, and has been the subject of voluminous debates and controversy. Some have advocated removal of the numerous weirs or dams, which, while they do not affect the fall of the river as a whole, cut it up into steps or sections, having only such a gradient as the water itself in its ordinary flow assumes, that is probably only ·2 or ·3 inches per mile, but the general gradient of the river is 21 inches per mile, and the fall of the water over weirs does not assist the flow above them. But the removal of weirs would have disastrous effects on the amenities and sanitary condition of the river as well as on the navigation, which would be practically closed.

* From the Report of the Royal Commission on the water supply within the Metropolitan area.

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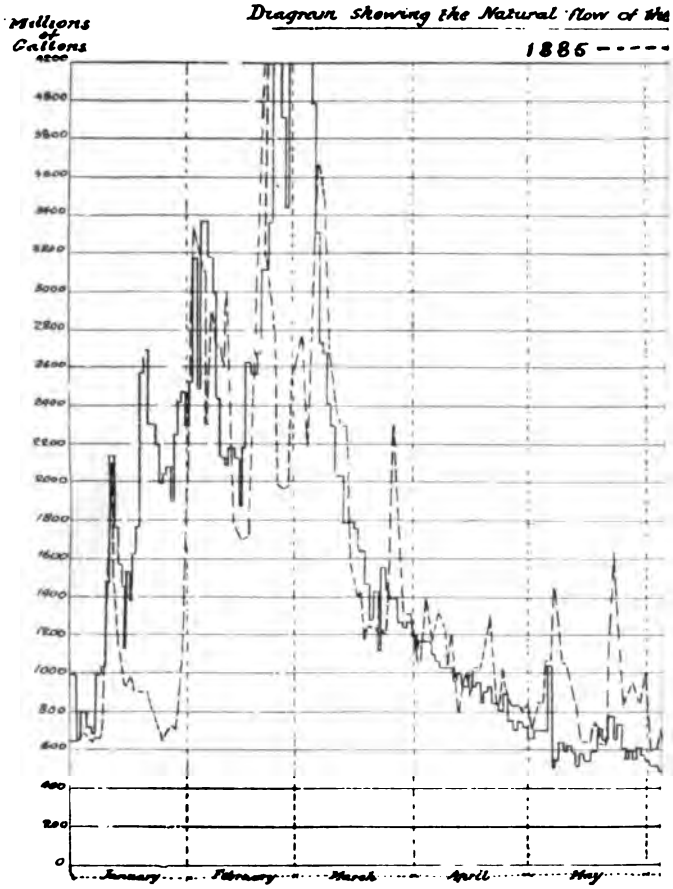
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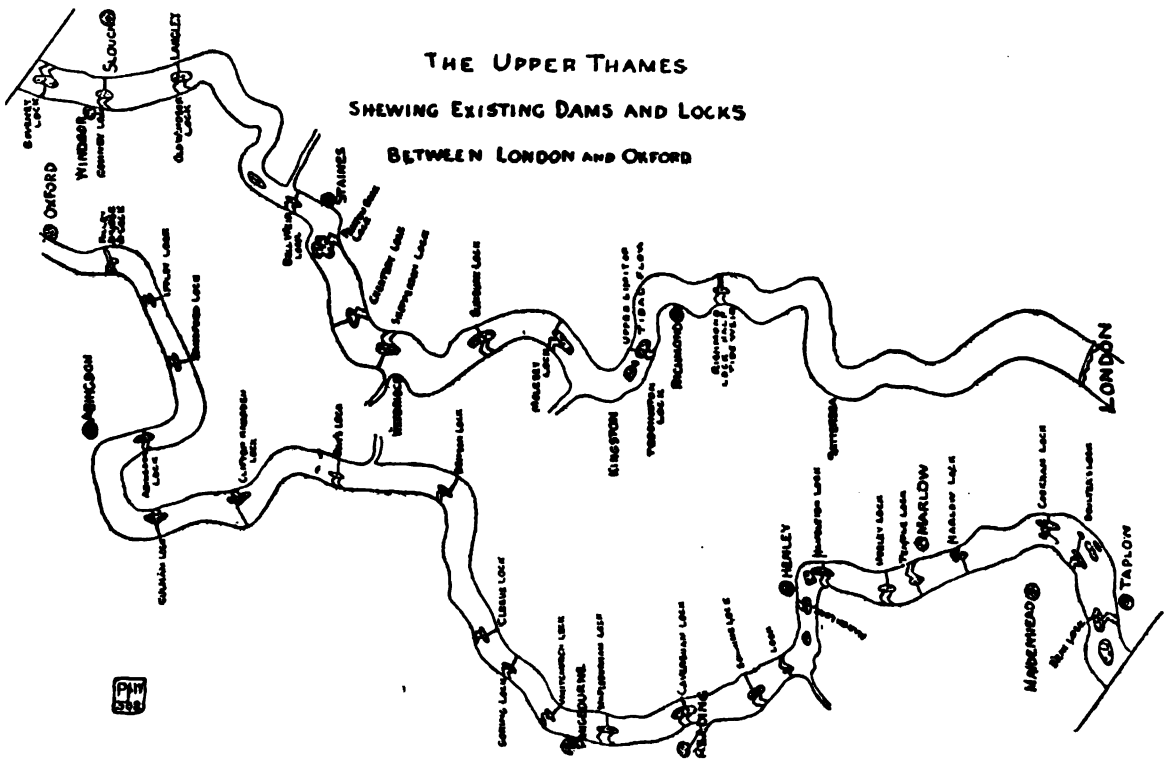
Some part of the flood waters will be taken in by the new reservoirs at Staines, &c., but there is only one practicable method of flood-water removal in the upper Thames, viz., a drainage canal or covered drain. The necessities of the growing population seem to point to a parallel drain as the proper solution.

But below Teddington Weir the upper river floods have no important effect, except when very high spring tides back up the upland water between Teddington and London on the flood tide. On these occasions the sewers are usually gorged with the rainfall, the storm overflows are drowned, the sewers and drains backed up and full to overflowing, and in the low areas of London the drainage flows back into the streets



and basements, until the ebb tide has fallen low enough to allow the storm overflows to discharge into the river.

The same results, however, frequently occur without any heavy freshet in the upper river, from extraordinary high tides.

But it must be remembered that, so long as the lower river water is below the crest of Teddington Weir, the tidal water can have no effect whatever in aiding or checking the flow of the river above Teddington. Only on very rare occasions has the tide overtopped the weir. This occurred on March 20th, 1874, and on November 15th, 1875, the tide water ascended as far as Kingston.

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TIDAL FLOODING.—But tidal flooding has occurred on a great many dates; in fact always occurs several times every year. The following are selected as a few well-authenticated instances of abnormal tides :—

In the year 1099 the banks were overflowed.

In 1114 and 1158, and on December 13th, 1717, the tide fell so low after high spring tides that people walked across the river-bed and under London Bridge.

On February 10th, 1238, and December 7th, 1663, Westminster Palace and Whitehall were flooded.

In 1214 the banks burst and the country was under water for six miles from the river; and again in 1270, and on November 6th, 1574, and on September 28th, 1764.

Double tides (that is a second high water after partial ebb) occurred on September 30th, 1555, January 26th and 27th, 1564, and November 6th, 1574.

The highest known tides occurred on March 20th, 1874 (when it reached 4 feet 4 inches above Trinity), and again on November 5th, 1875 (when it reached 4 feet 9 inches above Trinity).

MAINTENANCE OF RÉGIME OF TIDAL RIVERS.—The policy of all engineers in respect of tidal rivers has always been to increase rather than retard their volume and current, in order by its increased scour to cleanse and keep open the channel. A sluggish flow, with silty water, causes deposit and choking of the channel. But this can only be effected at the cost of increased range of tide; that is, the tide rises to a somewhat higher level and falls to a lower level than before the augmentation of the current, due to the momentum of the tidal wave becoming increased. Provision must therefore be made in such cases for raising the level of all embankments which keep the river from overflowing on to low-lying lands; and, on the other hand, the navigation depths become decreased at low water, demanding deeper dredging to replace the lost depth. This lowering of the low-water level usually occurs to a much greater extent than the corresponding increased level of high water. It is shown that in the case of the Clyde (p. 75), the high-water level after many years of dredging did not rise more than a foot, while the low-water level fell 9 feet 7 inches. In the Thames, since the removal of old London Bridge and certain shoals and construction of other works, the high-water line has been raised 1 foot and the low-water line lowered 4 feet, besides which the more rapid flow has accelerated the flood tide and retarded the ebb; caused by a 25 per cent. addition to the tidal volume as a consequence of these improvements.

The policy of engineers in maintaining and, if possible, augmenting the flow of a tidal river, is undoubtedly a sound one, *so long as the river remains tidal*, and this has been the almost invariable practice. Some of these engineers have, however, in particular instances, as we have seen (p. 8), recommended that the tides should be kept out of certain rivers, and assuming that this was effected by a dam, it becomes apparent that the old rule ceases to apply. The river becomes a lake in a river, into which the river flows at one end and out at the other over a dam or weir. Under these conditions the question of maintaining a channel is no longer dependent on the flow and ebb of a volume of tidal water, and the only remaining circumstance to be dealt with is the possible silting up of the lake by deposit from upland water.

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With an open tidal river, silting occurs in a large measure from the estuary, by volumes of silt carried up by the flood tide and deposited in the slack water at high water. The following ebb may or may not remove it again. (*See* p. 78.)

In the Thames the silt is constantly in this way washed up and deposited according to the strength or slackness of the current, and thus also the river mud is circulated throughout the entire river and estuary, becoming densest in the neighbourhood of the London shipping area, and thinning out at each end. (*See* Section V.)

In 1905 the new L.C.C. Steamboat Service caused a strong wash on the foreshores between Greenwich and Chelsea, and in a few weeks removed nearly all the mud deposits, but this mud was all deposited again above and below this zone of the river.

OBSTRUCTIONS TO THE FLOW.—In a navigable tidal river obstructions to the flow are bound to grow up. These include those of natural and of artificial origin. Natural obstructions are sand or mud banks, deposits on foreshores, falling in of banks, &c. But artificial ones include bridges, piers, and abutments, half-tide weirs, jetties, campsheds, groynes, training walls, sunken vessels, moored vessels, projecting quays, dolphins, &c., all which in their way retard or obstruct the current and tend to reduce scour, or, as in the case of jetties and dolphins, concentrate it around them.

All these obstructions exist in some form in the Thames, and, while it remains tidal, must be regarded as detrimental. The Thames Conservancy naturally restricts their use—except the mooring of vessels in the stream, which is becoming an increasing practice and presents very considerable obstruction to the tidal flow. Dredgers, floating hospitals, steamboat piers, and similar fixed vessels are obstructions of a permanent kind also. In fact, the floating obstructions greatly exceed in effect all the other forms combined. Parts of the river are for about one-third its width obstructed by tiers of moored vessels, whose submerged hulls cut off a large part of the tidal section, especially at or near low tide.

THE ESTUARY AND ITS CHANNELS.—The estuary of the Thames is also that of the River Medway and its branches, and forms a large roughly triangular area, at the apex of which is the mouth of the Thames, having an area of about 300 square miles. The estuary is an inlet of the North Sea, and into it the sea flows and ebbs at each tide. This movement of the waters has formed the bed of the estuary into banks and channels lying in the general direction of ebb and flow. The bottom is sand and silt on the London clay, below which is the greensand. (*See* Fig. 6, p. 23.)

The volume of water entering the estuary each tide, allowing an average rise of 12 feet, is about 3,000 million tons, to which a quantity must be added, as already found (p. 25), equal to 108 million tons, which ascends the tidal river, and a further volume of about 30 million tons which ascends the Medway and other creeks and branches, making a total flow of 3,138 million tons each tide, which passes into and out of the estuary and the river.

The average upland flow of the Rivers Thames and Medway and affluents bears thus an exceedingly small proportion to this volume of tidal water of the estuary. The average daily flow of the river, *i.e.*, 1/365th part of 1,176,440,625 tons is 3,223,125

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tons, which is about 1/950th part of the total tidal water of the estuary, while the whole tidal flow of the river itself is only the 1/30th part of that of the estuary.

In this way we arrive at the significant fact that 96·6 per cent. of the estuary water is purely oscillatory, and it becomes matter for consideration to what extent the river water affects the channels of the estuary under these conditions.

So far as the river currents are concerned, it will be evident that their effect on the estuary water diminishes in proportion to the expansion of width and depth of the estuary below the river mouth, and that the greatest effect must therefore be at and near the river mouth, that is, at Holehaven. If the river water has any important effect on the channels below, it may be expected to be found between Thames Haven and the Nore, but this part of the estuary is not so deep or clear of sandbanks as farther down; in fact, the Thames Conservancy is about to dredge channels in this part to make the approach to Gravesend as deep as elsewhere, and obtained an Act of Parliament (1905) for this purpose. The shallowness hereabouts is attributed to the rapid widening of the river at this part of the estuary, causing slack water, and therefore silting, but there may be other reasons, more properly applicable to the estuary water, as the last given reason can only apply to the ebb tide. The flood tide from the estuary is here first penned in width in its progress to the river, causing slack water, only the central part being free to proceed without check. This seems to account for the wide deposits of mud and sand on both banks at Leigh and Southend on the north, and at Yantlet and Blyth sands on the south.

It may therefore be fairly inferred that the lower and central channels of the estuary have been formed and are maintained entirely by the estuary tidal water; the upper channels also owe their tidal section in the greater part to the same cause, and only to a fractional extent to the river tidal water, while the upland water is practically of infinitesimal account in reference to the estuary channels, although it is undoubtedly the cleansing factor in the tidal river, in which, being a comparatively narrow channel, it pushes down step by step the oscillating tidal water to the sea in the manner shown in diagram, Fig. 14, p. 27.

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SECTION V.

POLLUTION AND SILTING OF THE TIDAL WATERS.

PRESENT CONDITION OF THE THAMES WATERS.

An average analysis of the upland waters flowing over Teddington Weir gives the following (Dibdin):—

ANALYSIS OF THAMES WATER ABOVE TEDDINGTON, AT SUNBURY (DIBDIN):—

Suspended Matter	0·5360 Grs. per Gall.
Objectionable Matter	81 per cent. of the above.
Grains, per million galls.	434,160.
Organic Nitrogen in above	1·01 per cent.
Or. Gas. per million galls.	5,414.

In the tidal river the quality and condition of the water varies a great deal. At high water its analysis for 1895 was (Dibdin):—

	Grs. per Gall.
Total suspended matter	2·92
Chlorine	478·9
Ammonia (free and albuminised)	·150
Dissolved Oxygen per cent. of complete aeration	49·0

and at low water:—

	Grs. per Gall.
Total suspended matter	6·20
Chlorine	182·8
Ammonia (free and albuminised)	·235
Dissolved Oxygen per cent. of complete aeration	45·8

At low water, therefore, the amount of salt water is very much less than at high water, as might be expected, and the general impurity greater.

At or near low water the current can always be seen boiling up the mud in comparatively clear water.

We will first consider the sources and quantities of pollution from all affluents into the tidal river and their effect on its water, &c.

SOURCES OF SILT AND POLLUTION.

These are many and must be dealt with separately. We will first consider that derived from the upper river.

FROM THE UPLAND WATERS.

The total average quantity of suspended matter in the upland water is given by various authorities as 1 grain per gallon. Sir W. Crookes says that it rarely exceeds 1½ grains, and is chiefly clay and vegetable matter. Multiplying, therefore, the total average flow over Teddington Weir per annum in gallons (8,500 million) by 1 grain we get an annual total of suspended matter of 20,000 tons which enters the tidal river.

FROM THE SEWAGE EFFLUENTS.

The next important source is the sewage effluents discharged at Barking and Crossness. The quantity now averages about 240 million gallons per day, and the

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analysis gives an average of suspended matter of 7 grains per gallon, which, multiplied by the quantity of effluent, gives a volume of 39,785 tons of depositable matter discharged into the tidal area per annum.

From the Storm Overflows.

Another source of pollution is the series of storm overflows which discharge at uncertain intervals the surplus rainfall and sewage which the sewers are unable to carry off. There are 50 of these at various points on the river, nearly all of them opening into the river at levels below high water. Messrs. Santo Crimp and Worth (Engineers to the Main Drainage Committee) estimate the total overflow from these annually at 3 per cent. of the total flow of the London sewers. The total flow is given by Worth and Crimp as 75,000 million gallons per annum; 3 per cent. of this volume is equal to 2,250 million gallons, and its analysis, as given by Dibdin, shows an average of 30·6 grains per gallon suspended matters, which, multiplied by the discharge in gallons, is equal to 5,355 tons per annum as the amount of depositable matter discharged into the tidal river by the storm overflows.

From Towns on the River.

There are, however, several smaller discharges of sewage effluents from towns on or near the river below London, such as Erith, Purfleet, Greenhithe, Grays, Northfleet, Tilbury and Gravesend, but the quantities discharged are not available, so that an estimate must be made on the basis of population of these combined districts, which amounts to about 95,000 persons. The average discharge of London sewage effluents per head of population is 36 gallons per day, which, multiplied by the population and by 30 grains per gallon, gives a total discharge of depositable matter from these sources of 2,770 tons per annum.

From the Marshes.

Another calculable source of pollution is the run-off from the low marsh lands and other unsewered districts which discharge into the tidal river by sluices at low water. The area of these may be estimated at a total of 62,000 acres from which the annual run-off of surface drainage will amount to 21,700,000 tons at 350 tons per acre, assuming the run-off to equal 3½ inches of rainfall, which is the amount estimated by Dempsey.

The quality of this water is by no means low. It usually lies in the ditches for some days, and though contaminated by vegetable growth and decay, contains but little suspended matter. If we assume the average at 3 grains per gallon, we get a total of 1,136 tons as the annual discharge from this source.

From Shipping.

Another source of pollution not so easy to estimate is that derived from shipping in the river, from which bilge water, deck washings, and domestic filth are commonly thrown overboard. Of these the bilge water is usually very foul, from putrefying cargo refuse and so on, accumulated in the bilges. Deck washings remove dust, coal waste, ashes, and cargo refuse, while the domestic filth will include all the usual ordure that a similar number of persons would produce on shore.

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If we take the number of vessels of all classes entering the Port from the Board of Trade Returns as 16,649 per annum, and deduct one-half as entering the docks (in which their refuse is separately dealt with and does not enter the river), and allow an average of five persons remaining on board each vessel, we get a total of 8,325 vessels and of 41,625 persons; assuming that each vessel remains in the river five days on an average, as a basis of calculation, 8,325 by 5 by 5 equal 210,625 individual days. We may assume that an average of 250 gallons of bilge water is pumped daily from each vessel, and that it averages in suspended matter 30 grains per gallon, that is, equal to crude London sewage; this will give an annual discharge of 123 tons into the river. We may take the deck washings and other waste as amounting to a similar quantity of 123 tons per annum. There remains the domestic sewage from 8,325 vessels, averaging five persons each, or 41,625 persons which, at 36 gallons per day each, averaging the same as London sewage, or 30 grains per gallon, we get a total from this source of 17½ tons per annum.

Other Minor Sources.

There may be some minor sources of pollution, such as washings from wharves, deposits of dust and smoke from the town, but these cannot amount to any important figure, and may be covered by a general allowance of, say, 1,000 tons per annum. Putting the whole in tabular form we get the following results :—

	Tons per annum.
From the upper river	20,000
„ Sewage effluents, at Barking and Crossness	39,785
From the storm overflows	5,355
Effluents from other towns	2,770
Run-off from marsh lands	1,136
From Shipping—Bilges	123
„ „ Deck Waste	123
„ „ Sewage	17½
Miscellaneous sources	1,000
Total pollution per annum, averaging per day 192 tons	70,309½

Owing to the tidal oscillation, this total is spread over the whole area of the tidal river, and becomes either deposited on the bottom, or, remaining in suspension, is carried down to sea in course of many days.

Quantity of Suspended Matter in the Tidal Waters.

The analysis of the tidal water (p. 33) gives an average of 4·23 grains per gallon suspended matter, and if we multiply this by the volume of the tidal water, we shall get the total average weight of dry suspended matter in the river, *i.e.*, 167 million tons by 224 gallons per ton by 4·23 grains per gallon equals 12,270 tons in suspension.

Taking then the average flow of upland waters from p. 28 as 707 million gallons per day, containing 54 tons of matters in suspension, and dividing it into the cubic volume of the tidal river, we get 53 days as the average period of oscillation during which the whole tidal water is pushed out of the river by the upland flow.

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If then we calculate from the table (p. 35) the daily discharge of pollution into the river, and multiply this by the average number of days of oscillation as above, we shall get a quantity equal to 10,179 tons, theoretically, approximating to that of the total average suspended matter in the tidal river at an average date which, allowing something for deposit or washing up of previous deposits, approximately equals the total given above (12,270 tons).

Deposit of Mud in the Docks.

A large quantity of river mud is annually dredged from the Docks by the Dock Companies, which consists of a part of the suspended matter from the river water pumped into the docks and deposited there. This water passes out into the river again by locking, after it has deposited most of its silt in the dock basins, from whence the silt is regularly dredged and sent down river to be dumped into the Barrow deeps. The quantity of mud dredged is about 700,000 tons annually, and the cost £32,000. (*See* Dock Companies' Reports).

But the total entry of depositable matters into the river we have found to be only 70,000 tons of dry material annually, or, as mud, equal to about one-third of the amount of wet mud dredged out of the Docks, which proves that the other two-thirds, *i.e.*, 466,000 tons, consists chiefly of mud washed up by the scour of the tides from the river banks and the estuary; in other words, the river scours up river a very large quantity of mud, and the Docks form convenient mud traps. If they ceased to exist, then the mud would remain in suspension and be gradually carried out to sea or be deposited in backwaters.

As the Dock and Canal Companies have no sources of fresh water to keep up the levels of their basins, they have to pump the greater part of their water used for locking from the river, making up as much as they can from the high tides through their gates without pumping; but as their inner basins are kept at from 1 foot to 2 feet above H.W.S.T., only the outer basins can be replenished in this way.

Disposal of the River Pollution.

Having considered and tabulated the nature and extent of the various polluting matters, the next point to be determined is the ultimate destination and results of these and their effects on the river.

For this investigation the river may be considered as a long reservoir in which the water travels to and fro twice a day, and into which the various contaminations fall at different points. At one end a continuous supply of fresh water enters, and at the other, at each tidal oscillation, on the ebb, a quantity equal to this fresh water supply, but of contaminated water, is delivered out into the North Sea.

The effect of the tidal oscillation is to distribute all soilage throughout the entire tidal water, to east and west of its point of discharge into the river. It will also be evident that in this distribution the intensity of this pollution will diminish by dilution as it recedes from this point of discharge. This applies to all the sources of pollution except the first, that from the upper river, which has a continuous flow downward, checked, backed up, and reversed each tide, and thus mingling evenly with the tidal water.

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During the tidal flow the current is too strong (*see* p. 69) to permit of deposit of silt, and it is well understood that deposit only occurs on the slack of the tide at low and high water, and in creeks or backwaters, unscoured by the current.

That Thames mud is always in circulation is evident from its appearance, which is fresh, not set or covered with a hard stratum or green weed such as is the case with mud that has remained in one spot for a few weeks.

The river bottom and foreshores are not smooth, even surfaces, but formed into elevations and hollows, which latter hold the mud while the elevations are usually clear, as can be readily seen on the foreshores at any time.

Wave action—between high and low water—whether caused by wind or steamers, causes a wash on the shores which rapidly removes mud. Mud so removed can only, however, be carried as far as the tidal water travels—about 12½ to 13 miles at the most, and is almost sure to be again deposited at the return of the tide in the slack water.

The two principal sources of soilage are those from the upper river, and the sewage effluents and storm water combined. We will deal with these separately.

The matter in suspension from the upland water is chiefly clay, earth, and vegetable matter which, while it discolours the water, is not harmful. The clay, &c., is necessarily in the form of a very fine silt or it would have been deposited in the slow undisturbed water above Teddington. It therefore may be assumed that it remains in suspension in the more turbulent tidal waters; were it otherwise its deposit might be expected to take place a little below Teddington, but there is no evidence of this.

The quantity (20,000 tons annually), if deposited evenly over the tidal river as far as Gravesend, would cover it only to the depth of one-tenth of an inch per annum.

The sewage effluents and storm waters contain 45,140 tons annually of depositable matter, which, entering the tidal river about the middle of its length, is distributed east and west by the tidal oscillation; but in diminishing quantity at the ends of the tidal river, that is, in the upper reaches from Richmond to Teddington, and in the lower reaches from Erith to Gravesend.

In addition to this tapering off, due to distance from the sources of pollution, another important force is in operation, viz., the natural bacterial oxidation which prevails in every river. This subject is of such great importance that it is separately dealt with in Section XVIII. All chemists, including Drs. Frankland, Dupré, Clowes, Dibdin, Messrs. Harry Clark and X. H. Goodenough, are unanimous in emphasising the immense importance of this natural purification. The principle is now being almost universally applied to the treatment of sewage, and is superseding the chemical deposition and sewage-farm methods hitherto employed.

The question of whether the whole volume of soilage tends to choke up or silt up the river bottom can easily be determined from the table on p. 35. The entire quantity per annum, supposing it all should be deposited between Teddington and Gravesend, would only cover the river bottom to the thickness of one-sixth of an inch.

That most of it is carried out of the river into the estuary or the docks is clear from the existence of mud banks on all the shores of the estuary, as well as by the fact that the river mud banks do not as a whole increase. But it is possible, and indeed

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probable, that there is a general circulation of mud throughout both river and estuary, the circulation, sometimes east and sometimes west, being due to changes of weather and freshets.

All backwaters that have no fresh-water sluicing element of their own, however, are continually gathering mud and require periodical dredging. Every projection that can cause a slack eddy, whether vertical or horizontal, such as jetties, piers, dolphins, campsheds, and projecting wharves, causes deposit of mud. Tiers of barges near the shores tend to cause deposit, and the slack water on the inner side of bends in the river favours deposit, because the current runs to the outer side of the bend.

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SECTION VI.

RAINFALL AND SURFACE DRAINAGE.

So far as the tidal river is concerned, the rainfall and drainage of the upper river watershed only affect the upland flow over Teddington Weir. We are concerned here with that of the tidal river and its watershed, which latter may be taken as being the whole of the Thames Valley from Teddington to Gravesend, including the valleys of the Lea, Roding, Cray, Darent, Wandle, and the Brent Rivers, covering an area of 1,496 square miles. (*See* map, p. 101.)

In dry years the total rainfall has fallen as low as 16·74 inches in the year, and in wet years has been as high as 35·32 inches, but the average as given by Symons is usually taken as 26·33 inches in the Thames district.

THE RUN OFF, however, varies considerably from many causes. These include evaporation, cultivation, land drains, subsoil drains, deep pumping, and in towns the paving and roofs which carry off practically the entire rainfall direct to the drains, so that there is very little percolation and the subsoil becomes dry.

Rain falls on an average 155 days in the year. Of these, on 25 days it amounts to ¼ inch in 24 hours, or at the rate of 1/1000 inch per hour.

One quarter inch rainfall, in a paved and sewered district like London, conveys only half its fall to the sewers, the remainder is evaporated or percolates the soil.

Four-tenths of an inch, in the same way, gives 2½ tenths to the sewers. Small rains contribute nothing to the sewers.

EVAPORATION is the largest factor in this question, being due to solar heat, varied by the dryness of the atmosphere, porosity or imperviousness of the soil, and plant life. These conditions necessarily vary greatly in different places, so that no general statement can possibly cover all the conditions. As it would be tedious, however, to divide up this large area into numerous sections under each heading and calculate from them a general average, we will accept the averages that have been carefully worked out by well-known meteorologists, many of whom have spent much time on this subject.

For the purpose of a general figure for this drainage, so far as the marsh lands are concerned, we will take the average rainfall of 26·33 inches as given by Symons. He estimates the average evaporation as 15·83 inches, which leaves 8·42 inches as the average percolation into the soil. This was the amount fixed by Lord Balfour's Commission. That is to say the proportion which it has been found by gauging reaches the upper river.

Mr. Dempsey estimates the average evaporation as 57 per cent. of the rainfall, *i.e.*, 15 inches, which approximates closely to the above estimate. Mr. Tonbridge says: "The ratio of evaporation to percolation depends on a great variety of circumstances, to wit, the nature of the surface and subsoil, the nature and growth of the vegetation, the prevailing wind, the electrical condition of the atmosphere, the mean annual temperature, and the combined effect of maximum temperature on the movement of the atmosphere. Moreover, it is an established fact that earth highly charged with water gives rise to rapid evaporation, but as it becomes drier it retains the

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moisture with great force. Then, again, the depth to which water will penetrate subsoil depends greatly on the rate at which it falls; for instance, it was observed on one occasion that in the month of June, in the Bourbonnois, a rainfall of 3·02 inches in 84 minutes only penetrated into the soil to a depth of 2 inches, whilst a fine rain in the month of July, which gave only a depth of 1·04 inch in seven hours, penetrated the same soil to a depth of 4·4 inches."

Mr. Clayton Beadle, in his paper before the Sanitary Congress at Manchester, in 1902, in which he gives the history of the work of the Association, first as the Kent Water Preservation Association, and subsequently as the Underground Water Preservation Association, gives a summary of percolation figures arrived at by different observers :—

	Per Cent.
Mr. Greaves (ordinary soil), 22 years	26·57
Mr. Greaves, estimated average for Home Counties referred to by Gilbert	28·0
Dr. Dalton, 1796–1798	25·0
Mr. Dickenson, 1836–1843	42·5
M. Maurice, Geneva, 1798–1797, referred to M. Gasparin, Orange, South of France	39·0
1821–1822, by Gilbert	20·0
M. Risler, Caleves, near Nyon, Switzerland, 1867–1868	30·0
Lawes and Gilbert, through 20 in. soil, 1870–1875	36·0
Lawes and Gilbert, through 40 in. soil, 1870–1875	36·0
Lawes and Gilbert, through 50 in. soil, 1870–1875	28·6
Mr. Longridge, 10,500 acres, period 10 years	36·5
Mr. Longridge, 125,000 acres, period 10 years	27·55
Mr. Longridge, 125,000 acres, period 10 years	33·0
Sir John Evans (three-eighths of the rainfall)..	37·6
Mr. Beadle's calculated average of above 14 figures..	31·93
Sir J. H. Gilbert's average for 5 observers	31·3
Mr. Longridge's average of three observers	32·35
Messrs. Lawes and Gilbert	33·8

Taking, then, Mr. Beadle's average at 31·93 per cent., or, say, 32 per cent. of the rainfall (26·33), we get 8·42 inches as the average percolation.

Mr. Urban Smith says: "The River Lea yields on the average, including flood waters, a fraction over 7 inches of the rainfall on the catchment area. The River Colne (another tributary of the Thames) also yields on the average 7 inches, including surface waters. The Thames above Teddington gives an average yield of 8·61 inches, but in the Thames basin there is a much larger proportion of impervious soil than in either the valleys of the Lea or Colne, or in the Kent district, the consequence being that a large quantity of surface water flows into the Thames before it can be evaporated, and occasionally floods that river."

We may now summarise the estimated quantities of upland waters which enter the Thames at various points from the foregoing data as follows :—

	Tons.
The total rainfall per annum of the Upper Thames Basin is 8,030,597,142 tons. Of this, the average annual flow of the Upper Thames, including the water abstracted for the London Water Supply ..	1,521,076,825
Run-off from the Lower Thames Watershed at 8·61 ins. of rainfall ..	833,272,000
Tons per annum	2,354,348,825

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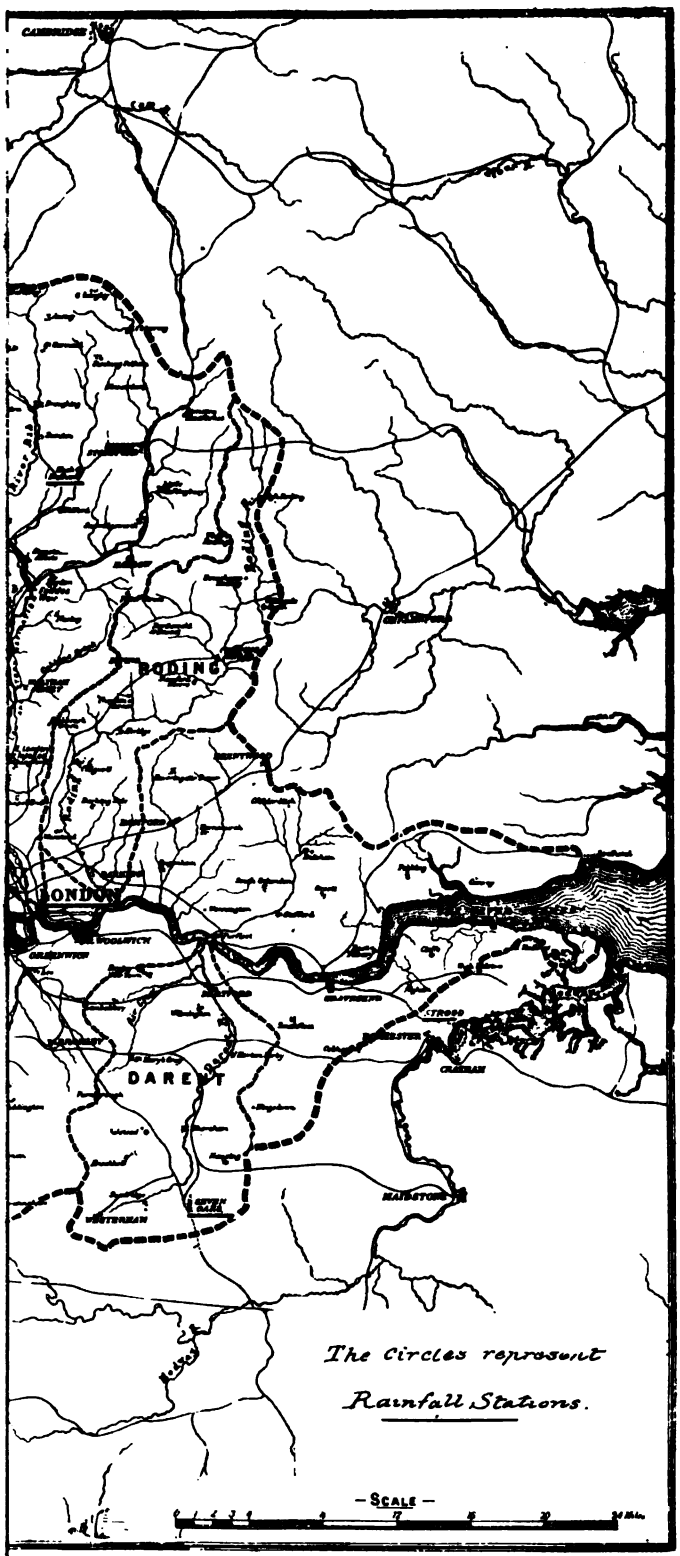
CAMBRIDGE
BOURNE
LONDON
GREENWICH
WOOLWICH
DARENT
CROYDON
MAIDSTONE
The Circles represent
Rainfall Stations.
— SCALE —

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Of the foregoing, the water abstracted by the London Water Board, amounting to 344,636,200 tons per annum, reappears partly with the sewage effluent at Barking and Crossness which amounts to 400,000,000 tons per annum.

A Report presented by the Engineer to the L.C.C. in February, 1903, on the shrinkage of the Thames and Lea Rivers, shows that since 1850 there has been a marked decrease in the rainfall of from 6½ to 10¾ per cent., and a still greater decrease in the run-off by the river of from 11¾ to 23¼ per cent.; and a similar decrease has taken place in the Lea rainfall and flow, which the Report attributes to diminution in the annual rainfall, in the percentage which reaches the river and the increase of pumping to supply increase of population.

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SECTION VII.

THE PROPOSED DAM OR BARRAGE.

Its Details and Mode of Construction.

Barring out the tides in a tidal river is effected by the construction of a Weir, Dam, or Barrage, as it is variously termed. Such a work consists essentially of an embankment across the river, built up above the level of the highest tides. This work must include provision for the overflow of the upland water; and where the river is navigable and frequented by shipping, means must be provided for passing vessels up and down by locks, inclined planes, or lifts.

Circumstances Governing the Selection of Site.

In the Thames the position of the proposed dam is a matter of the greatest importance, and dependent largely on the needs of navigation as well as of local circumstances. The volume of shipping is very great: expeditious passage and avoidance of risk thus become important considerations, so that the site selected should be one where there is no tidal delay, and at a point which can always be reached even at dead low water.

This condition, of sufficient depth at low water, could be satisfied at any point below Purfleet, except for a short distance below Sea Reach, near the Leigh Middle Sand, where the depth shoals to 26 or 27 feet. This part of the upper estuary, however, is now being dredged to 30 feet by the Thames Conservancy Board.

Gravesend is the point universally adopted by shipping as a waiting place practically approachable at all states of the tide. Here pilots are taken for the river. It also lies just below the Tilbury Docks, which ought, if possible, to be included in the dockised area if a dam is constructed, as it would otherwise be still subject to tidal conditions as to entry and exit of vessels, the largest class of which now frequent it. The outer sill of its entrance lock is 23 feet 3 inches below L.W.O.S.T., so that vessels of more than 22 feet draught could not enter the lock at low water, and the present cost of mudding the docks would have to be continued.

The width of the river at Gravesend is very little greater than at and below Purfleet, so that on the point of cost there is little to choose between these positions.

A further consideration in favour of the lower site is the greater area of the dockised river thus created, as also the increased river frontage which would be rendered available for wharfage or manufacturing sites, amounting to 14 miles of frontage.

Positions still lower than Gravesend have been recommended, such as Thames Haven, where, however, the river is more than three times as wide as at Gravesend, although the channel only occupies one-half of this width, and the depth of water in it is much less than at Gravesend. No advantage corresponding with the great excess of cost this proposal would involve seems to attach to this alternative.

Foundation.

As to foundation, which is of prime importance, the Gravesend site certainly has an advantage, as the chalk extends across the river and forms an admirable base

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Fig. 16.

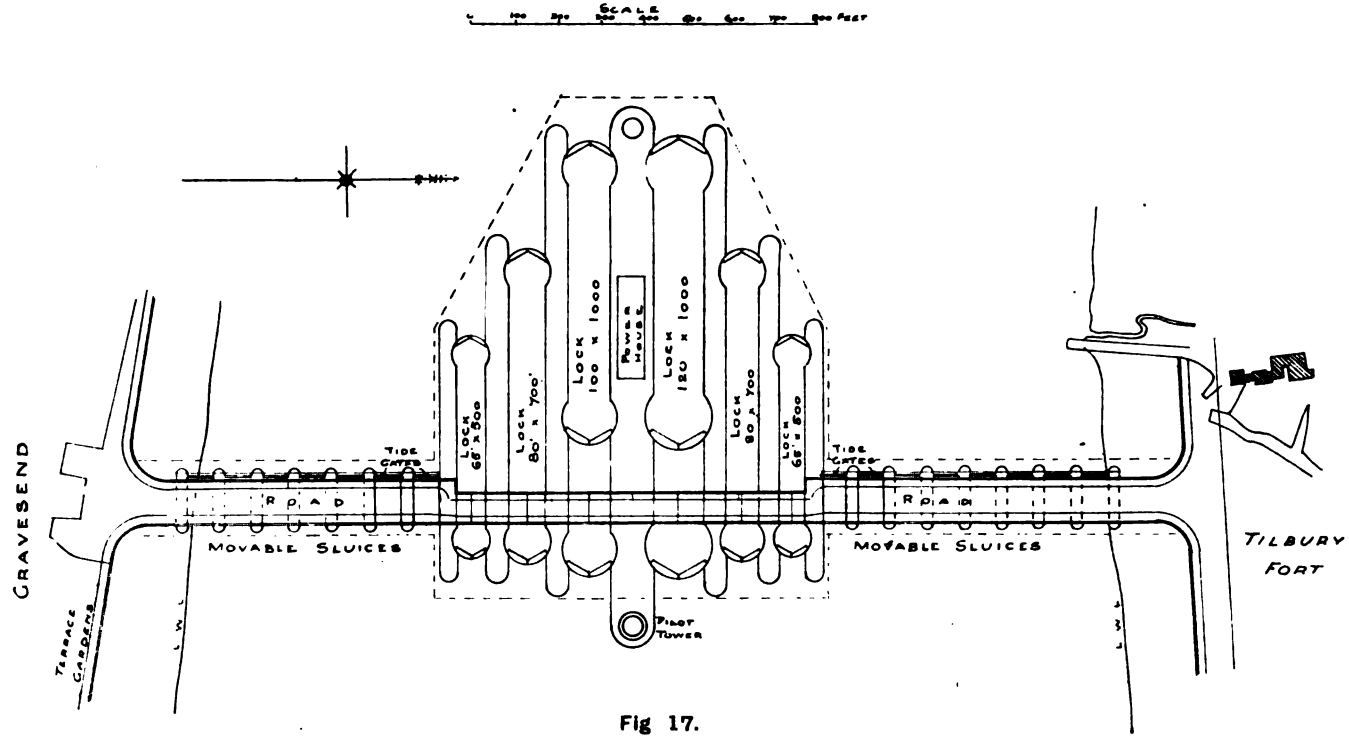

Fig 17.

PLAN AND ELEVATION OF THE PROPOSED DAM, LOCKS, SLUICES AND TIDE GATES.

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for constructing a dam. It is easily worked and levelled, is of great depth and will

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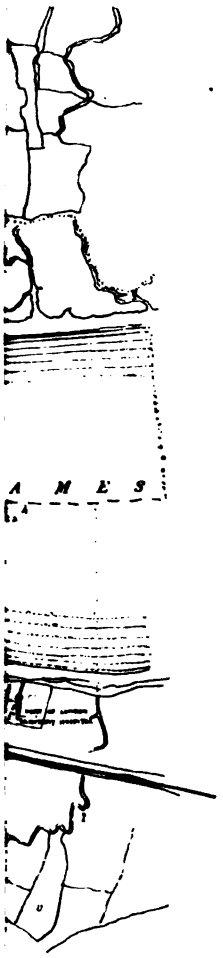
SOUTH.

M. Am. C. E.



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for constructing a dam. It is easily worked and levelled, is of great depth and will bear enormous pressures safely.

To what extent it is covered with sand and mud is not known, but it forms the surface rock on the south side, and is known to be at a depth of about 40 feet at Tilbury, so that the river channel has been cut in it. The probability, therefore, is that it is almost immediately below the river bottom, but this can only be determined by borings.

Approaches.

By water, the dam, if at Gravesend, will be approachable at all times of tide, east or west, thus enabling shipping to utilise the many hours of tide waiting now necessary under tidal conditions.

By land, the dam will connect Kent and Essex, *via* Gravesend and Tilbury, to both of which there are numerous roads.

Rail communication is of even greater importance, as, if it can be carried across the river at this point, a direct route from the Midlands and the North to the Continental ports can be established by the Tilbury Railway on the north and the S.E. and C. Railway lines on the south. (*See* map.)

Construction of Dam or Barrage.

The plans of such a work must necessarily require the most careful consideration, not because the engineering difficulties are great, but that provision may be made for every eventuality, present or future, so far as these can be foreseen. The requirements of shipping, arrangements for locking rapidly, disposal of flood waters, provision for cross-river road and rail traffic and foot passengers, signalling, marshalling traffic and many minor points have to be studied and proper provision made in such a manner as to be capable of great expansion in future.

From information available from official sources, and calculations based on the growth of trade and population, the dimensions of the proposed structure, as given in the following plans and sections, have been prepared.

The structure (*see* Figs. 16 to 23) consists of a straight monolith wall of Portland cement concrete, faced with granite, founded on the chalk and carried up to 6 feet above the highest known tide.

The upper surface of roadway and foot pavements is 100 feet wide, flanked with granite parapets, and the base or foundation width is 175 feet, in which is contained the tunnels for road and rail traffic to avoid interruptions from the frequent passage of vessels through the locks.

Locks.

The central portion is occupied by six locks of different dimensions. The sills of these locks being placed at 42 feet 6 inches below O.D., will give a minimum depth of water at L.W.O.S.T. of 35 feet. (*See* Figs. 18 and 20.)

Sluices.

Between the group of locks and each shore a series of sluices will be constructed, occupying nearly the entire length available, 60 in number, each of a width of 15 feet,

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and separated by massive stone piers 25 feet thick by 150 feet long, carried up from the concrete base of the sluices in the same manner as the piers of an ordinary stone bridge. A series of arches connecting the tops of these piers will form the superstructure and roadway. (*See* Figs. 21 and 22.)

The sluices will be of steel, balanced and movable in roller slides, operated by hydraulic gear so that each or all of them can be rapidly raised or lowered to govern the level of water in the river above.

Scouring Sluices.

Six of these will be constructed in the base of the dam, and operated as often as found necessary to scour the bed of the river below the dam, to keep open the approaches to the locks. Whether these sluices will be actually required or not is discussed in Section XV.

Power House, &c.

The working of the lock gates, sluices, and hauling capstans will be controlled from a pilot tower and power house, containing modern hydraulic and electric machinery of the latest type, designed to meet every possible contingency. This building may be constructed on or contained in the central pier of the system of locks.

The arrangements of this power plant must include means for preventing the most remote possibility of either accidental or wilful injury to any essential part, which might prevent the operation of the lock gates, &c.

Should military or other considerations deem it desirable, a bye-pass canal could be constructed through the Tilbury Docks for the passage of vessels in case of emergency, utilising its existing basin and entrance as part of the route. (*See* map, p. 43.)

Mode of Construction.

The construction of the dam will have to proceed without materially interfering with the traffic of the river as now conducted, but which may require to be marshalled somewhat differently.

Three years is about the period that will be occupied in construction ; and as the works will proceed gradually, the shipping will become accustomed to the changes necessary in navigating the Gravesend Reach and Northfleet Hope.

It may be desirable, for instance, to transfer the waiting place from Gravesend Reach to the reach above the dam, so that vessels going up river may pass the works singly, and the fleet, on starting up river with the flood, will not have to pass the obstructions of the works in progress.

Tugs will be desirable also to convey vessels past the works, and an effective system of signalling arranged, with provision of floating booms and fenders.

But the actual extent of the obstruction to traffic can be reduced to a small one by adopting the order of construction shown in the figures.

Figs. 18, 19 and 20 show a plan, longitudinal and cross sections, of two piers of the lock divisions to be first constructed in the middle of the river. The suggested order of procedure being as follows :—

(1) Lay down concrete base for the entire structure after clearing foundation down to the chalk.

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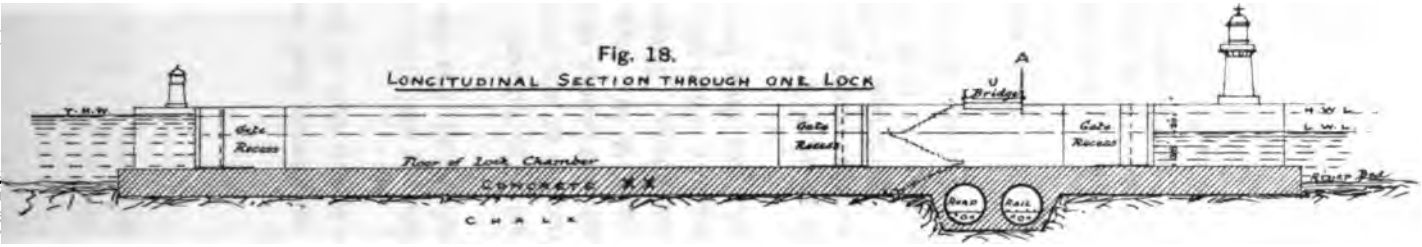

Fig. 18.

LONGITUDINAL SECTION THROUGH ONE LOCK

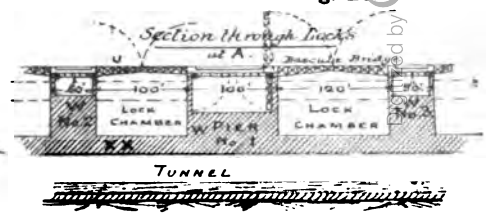

Fig. 20.

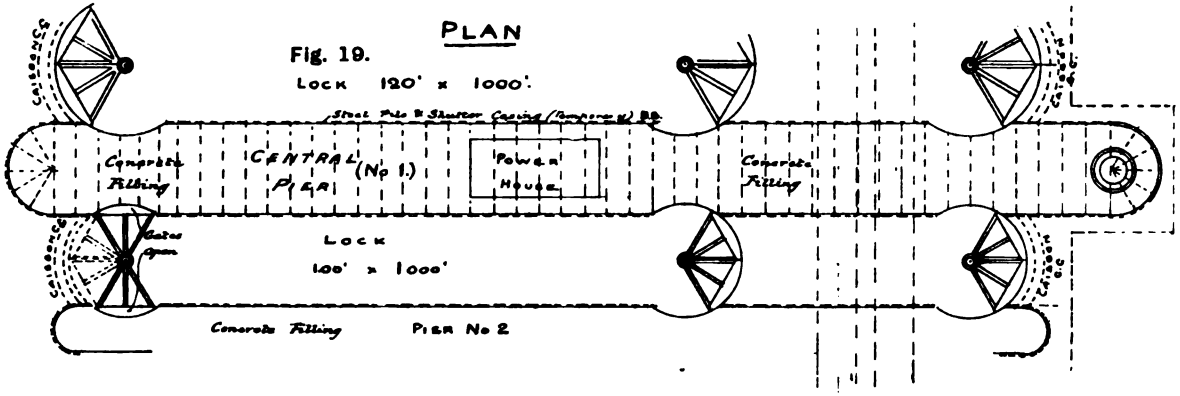

Fig. 19.

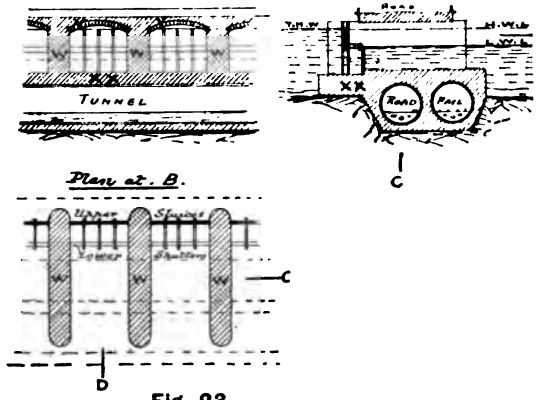

Fig. 21. *Sections of Sluice Ways at B.C.D* Fig. 22.

Fig. 23.

DETAILS OF THE PROPOSED DAM AND SLUICES.

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(2) Fix timber pile staging around one entire pier (say, No. 1).
(3) Fix the sheet piles and panels B.B. forming the enclosure of Pier No. 1 with cross struts.
(4) Fill same with masonry and concrete.
(5) Remove the staging and refix for Pier No. 2.
(6) Proceed as for No. 1, and remove staging for No. 3.
(7) Float out and sink two end caissons C.C. to form temporary lock ends.
(8) Pump out the lock space and fix cylinder gates as shown and all internal fittings and scouring sluices.
(9) Remove the caissons and throw open the lock for tideway and river traffic.
(10) Proceed with piers Nos. 3, 4, &c., in the same order, and also the piers between the sluices.

The foregoing method involves very little interference with the current or the traffic, there being only two or three piers in course of construction at any one time. When the series of piers and locks have been completed, the dam will consist of a mass concrete foundation X.X., carrying a number of masonry piers W.W., supporting arches V.V., and movable bridges U.U., forming the superstructure. Through all these the tide may be allowed to circulate freely until the closing day, when the sluices can be closed at high water, as also the lock gates, the traffic can then be worked through the locks.

The area of section of the river at the site of the dam at H.W.S.T. is 12,800 square yards, and at L.W.S.T. it is 8,000 square yards, the average speed of current being 2 miles per hour or 3 feet per second (*see* p. 23). The obstruction to the tide of the piers and foundation will be due to their sectional area, and at H.W.S.T. this will be 5,727 square yards, or 7/16ths of the available tidal area, and at L.W.S.T. 4,523 square yards, or 9/16ths of the tidal area.

Most of the traffic now passes up river during the first half of the flood, and down during the last half of the ebb.

At high water the increase of current will be to $3\frac{3}{4}$ miles per hour, and near low water to $4\frac{1}{4}$ miles per hour, due to the reduction of the tidal section of the river at the works. This will have no material effect on the navigation, but it will be desirable that an efficient organisation of the river traffic at this point should be maintained in place of the promiscuous and irresponsible method now in use.

Navigation at Gravesend under Tidal Conditions.

Under existing conditions there is an accumulation of shipping in Gravesend Reach between high and low water, more or less obstructing the fair-way, and all waiting for the flood to start. These all start off nearly together, but at various rates of speed, and are quickly followed by a fleet of sailing barges from the cement works of the Medway and Thames side at Northfleet and Grays; their object being to reach the docks and wharves a little before high water. Here they have to lay to until they can pass the locks or get alongside their berths, passing other vessels coming out of dock outward bound.

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In fine weather, or even clear, ordinary, or bad weather, these manœuvres are not difficult to an experienced seaman, though many collisions occur. But in thick or stormy weather it is impossible to avoid accidents. The drift of the tide makes steering uncertain and difficult; sailing barges are tacking across the stream in all directions, and numerous small craft drifting or steaming in the fair-way; added to which are the obstructions of moored vessels and dredgers.

In fogs the fleets accumulate at Gravesend until as many as 200 vessels have been fogbound there, waiting for tides. These must be moored fore and aft, as there is not room to swing; new arrivals come in behind and outward vessels drift past on the ebb, rendering the dangers of collision very great and imminent. It is remarkable evidence of the great average ability of the modern sea captain and his staff that comparatively few accidents do occur, but this does not go to the credit of the system.

Navigation at Gravesend under Non-tidal Conditions.

But if we eliminate the tides from Gravesend upwards, we create an entirely different set of conditions.

Every captain will then be aware that, as he can always reach Gravesend without delay—omitting sea fogs—on reaching Gravesend he can immediately be locked up into the non-tidal river at any hour day or night. He will therefore make his best run to Gravesend, irrespective of tides or hour of day or night. Arriving there he will not find himself one of a fleet of tide waiters, and, unless the locks have been exceptionally busy, he can go into lock direct. If he has to wait he will do so in dead water below the dam, not in a tideway; for the current for a mile or two below the dam will be almost imperceptible up or down. Unless there is a very strong north or south wind, it will not be necessary to moor. In practice he will slow down some distance below the dam, until he gets his signal to approach the lock, and then steam direct in, controlled by a tug or two alongside, if necessary, and hauled up by power capstans. When the lock is full of large and small craft, a few minutes suffices to close the gates and fill it. He can then steam out into the upper tideless river, with deep water everywhere, nearly up to the wharves and banks, and proceed to his berth at his leisure, or, if at night, he can, if he prefers, lay by until morning in absolute safety.

Regulating the River Traffic.

The river above the dam can be divided into two streams for up and down traffic, and a rule of the road ordered and enforced, as well as authorised mooring places provided and regulated as may be found necessary.

Navigation in Fogs.

In case of fogs, again the conditions are much changed in favour of the dam.

It is easy to devise a system of signalling to incoming vessels by the approach of a pilot boat, which can be sent to meet them and pilot them by a line ahead at a safe, slow pace to the locks, there being no current to contend with. There will be no fleet of vessels to be dealt with. In foggy weather the arrivals diminish greatly; they

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must necessarily proceed slowly, and, in the charge of river pilots, can be towed with absolute security to the locks, in the absence of current, and of moored vessels which now block the navigation.

After passing the locks and entering the river lake in tow of a boat or tug the ascent of the upper river is easy and certain, if slow; but a few hours lost in this way is a far better result than days lost in waiting at Gravesend, in imminent danger of collision, as is now the case every winter under tidal conditions, as is manifest from the following extracts :—

GREAT FOG OF DECEMBER, 1904.

(From the *Gravesend and Northfleet Standard*, December 31st, 1904.)

The fog of the past week will long be remembered in London shipping circles because of the enormous losses which it entailed upon shipowners and merchants. Shipping men, who alone can estimate it even approximately, put down the damage (says the *Daily Express*) at from a million and a quarter to a million and a half a day, or something approaching £10,000,000 for the week. During seven days traffic in the Thames was practically suspended the whole time—only the most reckless of captains daring to "up anchor." "When once the ships began to move," said an old Gravesend waterman, "they rushed out in double file, for all the world like a procession of soldiers. It was altogether the most curious sight—what with the wrecked bridges and davits and masts—that I ever saw in my life."

The cost of the disasters will fall upon the underwriters at Lloyd's. All damaged vessels will have to be surveyed, the majority dry-docked, and the whole cost—survey fees, dock charges, and repair account—paid by the insurers. At a low estimate, the bill for this will come to a couple of millions sterling for the week.

Official returns show that 51 vessels were in collision in the Thames Estuary during the prolonged fog last week. The Morocco liner "Orotava" has arrived at Dartmouth four days overdue from London. She reports having narrowly escaped being run down by a big liner in the Thames, and while lying to in the fog she was run into by a tug towing several barges, four of which sank.

FOG AND NAVIGATION.

To the Editor of the *Gravesend Standard*.

SIR,

For a whole week the river traffic has been practically at a standstill in consequence of the fog, although comparatively clear in the lower reaches. The river from Mucking (about five miles below Gravesend) has been very congested; ships have endeavoured to reach their destination without being aware of the great risk they were running. The result is that two ships have been sunk, over 25 collisions have occurred, and one magnificent and costly liner, whilst attempting to turn round to anchor, collided with three ships, and another large steamer coming up struck the liner on the starboard bow. Had she struck her amidships the liner would probably have sunk.

It is a well-known fact that in the Lower Hope and other reaches, in calm and hazy weather, the smoke from the manufactories hangs across the river like a curtain, and nothing is seen when going before the tide in time to avoid collisions. *I may add that if one thing more than another, from a seaman's practical point of view, would get the support of many to the consideration of the Barrage Scheme, it is that it would make the river tideless above, and practically still water for ten miles below it, and would do away with the great risk inseparable from navigating and manœuvring in the strong-running tides of the river. In a tideless river most of the vessels with perishable goods would have reached their destination in time for market.*

I remain, Sir, yours, &c.,

A TRINITY HOUSE SEA-PILOT.

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EXTRACTS FROM THE EVIDENCE OF THE ROYAL COMMISSION ON THE PORT OF LONDON.

R. CATTARNS. 3482. The smoke of the cement factories impedes navigation. The losses are most serious. The company of which I was manager has lost actually half a dozen steamers within my experience of 20 years. The steamers have been run down or in collision.

S. PENNEY. 4192. (*Q.*) I suppose that the question of fog is a very important thing in the navigation of large vessels ?

(*A.*) It is ; and not only fog, but one of the greatest curses that pilots have to deal with is the smoke from the cement factories ; from Gravesend down to the Lower Hope Reach some very serious collisions have been brought about by that smoke alone.

W. H. SANDFORD. 4392. Take from Northfleet until we arrive at Purfleet—I am speaking, of course, of calm, quiet weather—we are sometimes in a state of artificial fog, most dangerous to navigation and to life, almost equal to a fog.

Gravesend Reach is very bad. After two or three days' fog it gets into such a congested state that there is no room to navigate in at all. Barques come up from the Baltic, and they lie there as long as a fortnight at a time.

SIR THOMAS SUTHERLAND. 1992. We have been obliged to send ships which are already off the docks waiting to enter back to Gravesend. That is a very serious thing to be obliged to do. Then we say that ships on leaving the docks are sometimes overtaken by fog, and if that occurs in the shallow part of the river above Erith, the ship must get aground and incur considerable danger.

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SECTION VIII.

AT WHAT LEVEL SHOULD THE RIVER BE MAINTAINED.

This is a point requiring some consideration, as it will affect various interests differently, and must clearly be a matter of compromise among those affected.

So far as the works of the Barrage are concerned, it is immaterial what level is decided on, as any one level above L.W.S.T. can as easily be maintained as another, by adjusting the sluices at the dam.

The persons affected will be :—

1. The Dock Companies.
2. The Wharfingers.
3. The Canal Owners.
4. The Dry Dock Owners.
5. Riverside Manufacturers.
6. Other Frontagers.
7. The Drainage Authorities.
8. Low-lying lands and their Drainage Commissioners.
9. Owners of lands affected by saturation or percolation.

The proposed level is at Trinity high water, as fixed by Act of Parliament in 1805. This is at 12 feet 6 inches above Ordnance datum, which is 1 foot 3 inches above mean sea level.

FOR SHIPPING AND BARGE TRAFFIC, which is not included in the list above, any level above high water of neap tides will be an advantage, as all they require is plenty of depth and width for navigation and mooring.

1. THE DOCK COMPANIES maintain the levels of their basins as high as possible, in order to accommodate deep draught vessels; the tendency being to increase draught and tonnage. For passing in and out of their locks also as high a level as possible will be an advantage, because of the present levels of their sills. (*See* Longitudinal Section of River, p. 50).

To maintain the dock basins at any level above the current high-tide levels involves pumping from the river, as they have no land water supplies from which to make up their basins, and therefore draw all their lockage water from the river.

The St. Katherine's Docks, some of the basins of the London Docks, the East India Docks, the Tilbury Docks, and the Surrey Commercial Docks have no pumping power to raise their water levels, so that they depend on the high tides to make up their lockage water. All the other Docks have pumping plant, and they artificially raise the water levels to various heights varying from a few inches to as much as 3 feet 6 inches above Trinity high water in the case of the London Docks; but this is exceptional. In all the others the level is seldom more than 1 foot above Trinity high water.

If the level of the river is, therefore, maintained at Trinity high water as proposed, the unpumped docks will gain in depth of water, but the others will lose from a few inches to a foot or so, the worst case being the London Docks, where, however, if the height of 3 feet 6 inches above Trinity is necessary, they can continue pumping as now.

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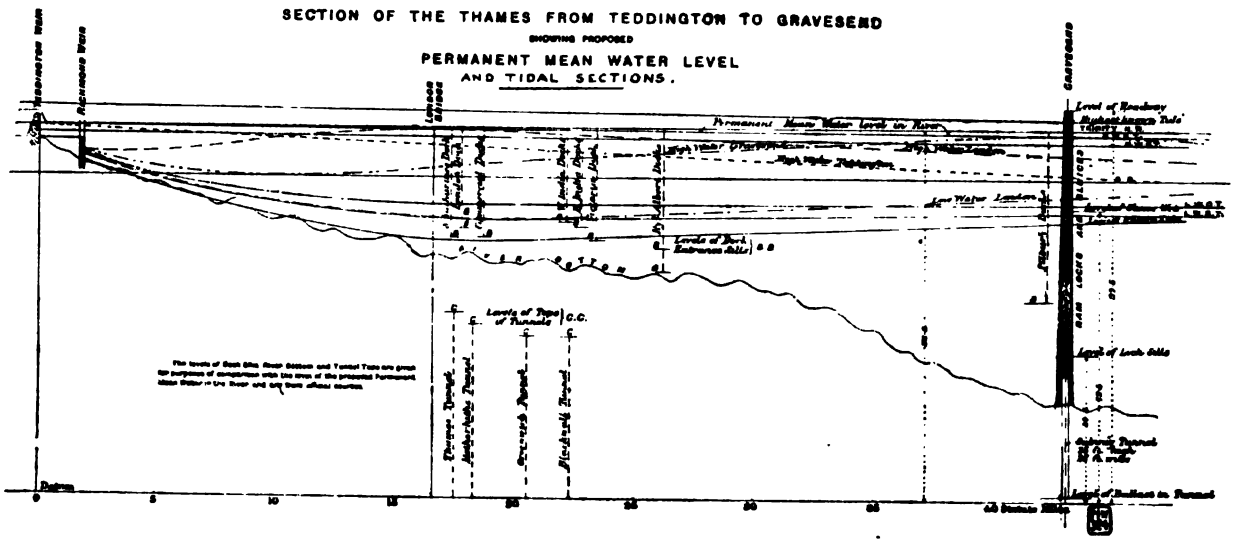
2. For the Wharfinger as high a level as possible will be an advantage, short of overflowing their quays; because very few of them have a sufficient depth fronting their wharves to take the larger class of steamers. A very few of them have as much as 16 feet at low water, but the great majority have less than 15 feet depth at H.W.S.T. Some additional depth could be obtained by dredging in some cases, but if this were carried down more than a very few feet it might entail serious subsidences.

With a dockised river, however, the wharfingers can construct short jetties without injuring the navigation, although such a policy in a tidal river, as now, could not be permitted, as it would interfere with the natural scour and cause dangerous obstructions to navigation in the tideway.



3. The Canals which enter the Thames are the Regent's Canal, the Grand Junction Canal, and the Surrey Canal, which latter, however, only reaches the river by way of the basins of the Surrey Commercial Dock.

The Regent's Canal formerly had a supply of land water from the Brent Reservoir, but now pumps all the water it requires for locking and maintaining its level from the Thames.

The Grand Junction Canal enters the Thames at Brentford by way of the Brent River, in which a permanent high-water level would be of benefit to the Canal Company.

The Canals may, therefore, be regarded as standing in the same relative positions as the Dock Companies so far as water level is concerned.

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4. THE DRY DOCKS, however, are undoubtedly dependent, as now conducted on the tidal action for filling and emptying their docks; the practice being to enter vessels at high water, close the caisson, and run the water out at low water, leaving the dock dry for repair of the vessel's bottom.

It is manifest, therefore, that any permanent level in the river will involve the erection and working of pumping plant to pump these docks dry, and proper provision must be made for this purpose.

5 & 6. THE RIVERSIDE MANUFACTURERS AND FRONTAGERS, however, will welcome a continuous high-water mark at any level below that of their quays, because it will enable them to carry on loading and discharging at all hours and greatly enhance the value of the river frontages.

7. THE DRAINAGE AUTHORITIES are, generally speaking, all upon the same basis as the London County Council so far as their outfalls and sewage treatment are concerned. As most of these outfalls are below high water, and very near to low-water level, it is obvious that any permanent level above low water will necessitate arrangements for pumping their effluents into the river above Trinity high water; or, in the alternative, intercepting drains must be constructed to take these effluents to a point below the dam. This subject is fully discussed in Section XVI. (p. 101), but the particular level of the permanent basin is matter of indifference, and will only affect the height of lift, and thus the H.P. of the pumps employed.

8. THE DRAINAGE OF LOW-LYING LANDS is dealt with in Section XVI. (p. 101), and the question of level in the river will only affect this interest so far as the hydraulic head of the river affects the sub-soil percolation. (*See* p. 82). A greater head of water will give a greater pressure on the subsoil water and force it to a higher level where the character of the soil permits. All water in such lands above a level of a few feet below the surface must of necessity be pumped, or led to drains discharging below the site of the dam, in order that these lands may be kept dry for building or other industrial purposes. (*See* Section XVI.)

9. LANDS AFFECTED BY SATURATION.—Where the saturation level is raised as a result of the permanent high water in the river, in lands where it will be injurious, the level must be kept down by pumping. It is impossible to map out such areas, however, because there are many districts where pumping for domestic, industrial, or towns' supplies now keeps down the saturation level to a point so low as to be injurious for farming operations, and lands formerly farmed have gone out of cultivation from this cause. In other places the saturation level is, or will be, too high for healthy dwellings to be constructed, and pumping or drainage must be resorted to; but it must be borne in mind that it is probable that—if dredging is stopped in the river bed—the river bottom will soon become sealed and nearly impermeable, so that the saturation of adjacent low lands will be unaffected by the river, but be due solely to rainfall. In Sec. XVI. it is shown that the general level of underground waters has been falling for many years past at the rate of 1 foot per annum, and it seems unlikely that any permanent raising of the river level can materially affect the general level of underground waters, which depends almost entirely on pumping from wells.

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PERIODICAL LOWERING OF THE WATER LEVEL.—It may, on consideration and enquiry, be found advantageous to lower the level in the river for a few days at stated times to enable repairs to walls, &c., to be executed. This is a matter that requires detailed enquiry as to the character and frequency of repairs. But it must be remembered, in this connection, that with a permanent high water such repairs will be greatly reduced in extent and frequency, as also that the constant pressure of the river on the walls tends to their stability.

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SECTION IX.

QUANTITY OF LOCKING WATER REQUIRED.

In the dry season of the year (August and September) the total average flow of upland waters is only 127 million cubic feet per day. But the work at the locks may be as great as at other times; so that it is desirable to calculate the volume of water required for lockage and estimate the surplus, if any, available for other purposes, such as sluicing.

The water area of the six locks is given on p. 58 as 38,098 superficial yards. The rise of tide at Gravesend is: springs, 18 feet; neaps, 15 feet; average rise 16½ feet.

As the locks may be assumed to be at work 24 hours per day, we must assume some proportion of day work to night work. This may be reasonably taken as 2—1, so that during 16 hours out of 24 three-fourths of the traffic will be probably dealt with.

But twice daily, within this period, there will be a level between the lake and estuary, when the gates can be all opened (in the same way as there is now a level between the river and the docks twice a day), leaving ten clear waterways of from 60 to 120 feet width for passage of shipping. The length of time these free passages can be utilised will be from 1 to 1½ hours, beyond which the difference of level may cause too great a current to admit of safe passage.

At other times the gates will be used.

As many vessels as possible will, of course, be passed through at the level, and the regulations adopted will provide for this. If the large vessels use the wider passages and the barges and craft the small ones, it will be easy to pass in one hour 60 large vessels up and down and 100 smaller vessels and barges. The provision of fenders and booms, with the absence of tidal current, will enable all these to steam or tow straight through, properly marshalled and regulated by signals. Tugs can be in attendance to tow all vessels and craft not under steam through the locks in strings of six or eight.

It will be possible also to regulate the level of the lake at Gravesend to correspond nearly with that of the sea at high water without affecting materially the level at London, so that the open locks may always be used at high water for as long a period as possible.

Assuming, then, that the maximum traffic (given on p. 58) is 745 vessels and craft (which is quite exceptional—the ordinary average being only 250), daily up and down, consisting of 245 vessels and 500 craft, &c., it will be possible to pass the above proportions of these without locking. The balance of 215 ships and 400 craft must be locked during 20 or 22 hours, during which the difference of level will be from a few inches to an average of 16½ feet, the average of which is about 8 feet.

The total tonnage of vessels and craft per day, as above, has been found to be 157,000, which, divided by the number of them, gives an average of 211 tons. The six locks can contain at one locking, when about half filled, 12 vessels and 24 craft

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in the proportion found to obtain in the general traffic, *i.e.*, one vessel to two craft, which x 211 tonnage = 7,596 tons tonnage displacement, plus the weight of the ships, which may be fairly taken at an equal amount or a total of 15,192 tons.

The average quantity of water required to fill the six locks for an average difference of level of 8 feet is 111,594 cubic yards, or 84,000 tons, from which must be deducted the displacement as above (15,192 tons), leaving a net quantity of 68,808 tons of water per average locking of the six locks. This, multiplied by the number of vessels and craft (615), divided by 36, as found above, gives 17 lockings of the six locks, and a total daily maximum usage of 1,555,311 cubic yards of lockage water per day, as against the total quantity of upland flow available in the dry season—4,717,000 cubic yards; and in the wet season 13,316,000 cubic yards.

There is, therefore, three times the quantity required in the dry season, and, of course, a very large surplus in the wet season; and even in abnormally dry years, if the quantity used exceeded the upland flow at any time, so as to lower the general level of the lake, this can readily be made good at high water by letting in sea water through the sluices or locks.

In the above calculation it is assumed that reasonable economy will be exercised in using the locks, filling them moderately full each time with large and small vessels and craft. In ordinary weather this will be easy, but in bad or foggy weather the lockings will have to be made to suit the traffic—not the other way, and economy of water postponed for better weather.

If in 40 years' time the traffic attains double the present proportions (though it is very unlikely that the exceptional maximum number of vessels of 745 per day named above will be exceeded), there will still be an ample supply of water for lockage and a surplus even in the dry season.

Additional locks can be constructed also in place of some of the sluices adjoining the locks (*see* Fig. 16, p. 44) should their need become apparent at any future time, without reconstructing the dam.

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SECTION X.

REGULATION OF THE LEVEL OF THE RIVER.

The Closing of the Barrage at Gravesend, when completed, will create a river lake or dockised river above it, extending to the next dam at Teddington, into which lake there will be a number of affluents of land water, as described (p. 28), amounting to a total of about 2,449 million cubic yards annually, or 7,531,500 cubic yards daily on the average.

The upland flow will move slowly down the lake, without oscillating up and down as it now does, with the tides, but arriving at Gravesend in exactly the same number of days as it now takes.

But the average flow gives no approximate idea of the extreme flows—maximum and minimum. In summer (August and September) the flow will be only 4¾ million cubic yards daily, although in winter (December-March) the flow may be anywhere between 8 million and 15 million cubic yards daily; so that it becomes a matter of enquiry whether these irregular supplies can be dealt with effectively without possibility of flooding any part of the adjoining lands, or even materially varying the level proposed to be maintained in the river lake.

The total area of the lake surface between Teddington and Gravesend is 48 million square yards, and the maximum ordinary flow of the upper river 15,116,000 cubic yards per day, to which must be added for the general sewage effluents 1,176,000 cubic yards, and for the springs and smaller sources 2,140,000 cubic yards per day, making a total maximum flow of 18,432,000 cubic yards per day. This quantity is equal to a rise of 10 inches in the entire area of the dockised river, as above, supposing that no water is discharged during the day at Gravesend.

But as the sluices to be provided there can be made to discharge as much as 90,000 cubic yards per minute, or 86 million cubic yards per day between the high tides, besides the large quantity required daily for locking (*see* p. 53), it is evident that there is abundant control in the regulation of the sluices for adjusting the level at all times.

It must be noted here that to maintain the flow of the upland water through the river lake a certain slight gradient of surface is necessary. Thus, taking the maximum flow as obtained above, a fall of ·22 inches per mile will enable it to run through the lake without raising its level. But this may be done either by raising the Teddington end or by lowering the Gravesend end of the lake level, the latter being, of course, preferable, to prevent increasing the general level during wet seasons.

As the distance between Teddington and Gravesend is 46½ miles, with the maximum flow as above, the difference of level will be 46½ × ·22 inches = 10·23 inches. This will be reduced in dry seasons to a gradient of about ·05 inches per mile, which × 46·5 = 2·32 inches difference of level. The actual level of the sluices will be a foot or two below these levels, to give sufficient sectional volume to the overflow —in accordance with the usual rules for depth of flow over the sill—for the volume of water passing. But these figures will all be reduced to some extent by the discharge

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of locking water (considered on p. 54) and, if the scouring sluices are required to be used at times, the quantities discharged by their means.

It will be seen, also, that flood waters amounting to the maximum flow may continue for several days without affecting, materially, the river level.

It must also be noted that in giving Trinity high water as the level proposed to be maintained, this is only an approximation, as the gradient of flow precludes a strictly horizontal surface at that level, or any other.

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SECTION XI.

CAPACITY OF THE LOCKS.

Much has been said by responsible and irresponsible persons as to the possibility —or, as they affirm—the impossibility of effectually locking the large number of vessels ascending and descending the river without unreasonable delays, so that it is desirable that the best available evidence may be adduced bearing on this question.

It may be pointed out in the first case that the construction of locks at Gravesend is, in effect, the transfer of the existing Docks' locks to Gravesend, as the latter will be no longer required. Vessels, therefore, locked at Gravesend do not require a second locking at the Docks.

But this applies only to a part of the shipping. The number of vessels which enter and clear from the Docks is stated in the Report of the Royal Commission on the Port of London as 9,989, but to this number must be added a very large number of barges entering and leaving the docks which do not come from Gravesend, but are the river carriers from dock to wharf, &c. These barges numbered in 1899 :—

London and India Company's Docks	137,193
Millwall Dock	40,000
Surrey Commercial Dock	22,050
Regent's Canal Dock	14,493
Total barges locked in and out	213,736

Besides which a large number of boats and tugs should be included, but of which there are no records.

This gives a total of 9,989 ships and 213,736 barges of all sizes, which are now annually locked in and out of dock by the existing locks in use, each ship and barge requiring two lockings. A careful enquiry as to these shows that 17 locks of all sizes, from 40 feet by 150 feet to 80 feet by 700 feet are in use, but many of them have very little traffic, while others are frequently used nearly to their full capacity.

This latter may be fairly judged from a statement by Mr. Duckham, Engineer and Manager of the Millwall Dock (Port of London Commission Minutes of Evidence, p. 50), that in one tide his lock had passed 22 ships, totalling a tonnage of 29,648 tons, and 146 barges. This was effected between about 1½ hours before high water and, say, two hours after high water (3½ hours), during part of which time, probably 1½ hours, the lock gates were open to the basin and river.

This lock is 450 feet long by 80 feet wide, and is therefore of moderate size. We find thus that the existing locks are in use on the average only for about three hours each tide, or six hours out of 24 per day; and that 18 locks pass daily at the present time 1,230 vessels and craft of all sizes in and out per day during six hours, or an average of 110 vessels and craft per lock per day.

The present number of ships of all sizes above 45 tons entered and cleared from the Port of London, in 1897, is given by the Board of Trade Returns at 71,215. To this must be added a number of small craft under 45 tons and vessels in ballast, making up a total traffic up and down river at Gravesend of about 100,000 vessels and craft

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of all sorts and sizes, which, divided by 365 days, gives 275 as the daily average. But the arrivals and departures are very irregular, dependent largely on the weather. So that it has been found by actual counting that as many as 745 vessels and craft of all sizes have passed Gravesend in one day of 24 hours, though this has been a very exceptional case—the result of detention by fog. Still the conditions must be met and ample provision made.

We can thus institute a comparison between the 17 locks in daily use in the river and those proposed to be in use at the dam. The comparison must take into account difference of capacity and mode of working. In these respects there are no existing locks that can be used as types.

The locks at the dam will be of the following dimensions :—

One of 1,000 feet long by 120 feet wide.
One of 1,000 feet long by 100 feet wide.
Two of 600 feet long by 80 feet wide.
Two of 400 feet long by 60 feet wide.
Total water area, 40,418 super. yards.

In addition to the locks, four tide gates are provided, totalling a width of opening of 200 feet to be opened only at high water for passage of barges and craft.

The total water area of the dock locks now in use is 39,430 super. yards, so that in capacity they are about equal to those proposed at the dam ; but as the former are at work only six hours out of 24, and the latter can work 24 hours, their working capacity is four times that of the former.

It has been shown by a calculation based on the maximum existing traffic (p. 54) that 17 lockings of the six locks, in 22 hours, would pass 615 vessels and craft, which is equal to less than one locking per hour.

It is further to be noted that the dock locks stand at nearly right-angles to the river, that vessels require to swing across the stream and the up and down traffic in entering or leaving, and this has to be done often with the tide running full ; whereas the locks of the dam will be in line with the river and in its centre, free from tide currents and provided with every known appliance for expediting the passage of the shipping, which must be considered as an added percentage in favour of the capacity of the Barrage locks.

The following further evidence as to the power of existing locks to pass a volume of shipping and barges is confirmatory of the foregoing.

The Eastham Lock (600 feet by 65 feet), Manchester Ship Canal, passes large vessels through with a rise of 13 feet in 19 minutes, and passes 22 vessels and 62 barges, &c., through in six hours, as to which the Engineer (Mr. W. H. Hunter) states " there is no doubt that the limit of capacity of the locks has not yet been approached."

Liverpool Docks.—The Engineer to the Mersey Dock and Harbour Board writes :—

" The record working of our two 65-feet Langton River Entrances appears to have been on January 3rd, 1903 (afternoon tide), when 17 vessels (or 45,647 tons) and 15 flats passed in and out. The highest tide's work at the three Sandon River Entrances

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(40, 80, and 100 feet wide) occurred on September 23rd, 1905 (Afternoon tide), being 18 vessels (or 55,866 tons) and 75 flats."

A tide work being about three to four hours.

Probable Increase of River Traffic.

This point must, of course, be considered, and the capacity of the locks, &c., designed to meet every future contingency within a reasonable number of years.

The rate of increase of the trade of the Port has been given on p. 2, and it is there shown that provision for the future must take the form of means for dealing with larger vessels, a steady decrease in number of small vessels and of sailing ships; an increase in steamships; more rapid handling, entailing more frequent journeys (which tends to retard the increase in numbers of ships); and a corresponding increase in number of barges, or an equivalent introduction of motor barges as carriers from ship to wharf, ship to ship, ship to dock, and so on, which latter is by far the most probable assumption.

The population of London and district is undoubtedly the principal determining factor as to growth of river traffic, and on its basis it could easily be calculated with some approach to certainty, in the same way as the London Water Commission estimated the future requirements of London up to the year 1941, on the basis of increase of population.

But there are two other factors which vary the calculation, viz.:—the *entrepôt* trade and the distribution of goods outside the London area from deliveries in the Port of London.

As to the *entrepôt*, or transhipment trade, the evidence of witnesses (Sir R. Giffen and Mr. G. L. Gomme) before the Royal Commission on the Port of London, shows that it has been decreasing since 1870 from 83·8 per cent. of the total import shipping trade of the United Kingdom to 38·5 per cent. in 1899 (excepting tea and goods other than liquors and tobacco, which have about maintained an equality); much of the deficit having gone to other British ports. The distribution of this branch of trade is undergoing changes with the improvements introduced in the ports affected.

There are no figures available to show the proportion of goods landed at the Port of London which is sent into the country outside the London district, so that that element must be left out of account.

The increase of population of London is held by Mr. G. L. Gomme to be the determining factor. This has increased in proportion to the whole population of the United Kingdom from 10½ per cent. in 1856, and to 15½ per cent. in 1896, while in the same period of 40 years the import trade of London has diminished in nearly all respects; but as it is manifest that a larger population must demand a larger import, it follows that the balance of imports must have reached London by other means—chiefly the railways.

The actual proportionate rate of increase of population is less for each decade than the last; and also the proportion for the whole Kingdom. On this basis the London Water Commission held that the increase up to 1941 might be estimated on an increased population of 12 millions, although the figures of actual rate of increase

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did not bear out so large an addition. But on a figure of 12 millions, which is just double the present population, we may fairly estimate the increase of shipping at double the present tonnage, allowing a deduction due to the increased supply of London from other ports by rail, which amounts to the difference between the relative rates of increase of tonnage and population, as given by Mr. G. L. Gomme, as follows :—

	Tonnages.		Population.	
	1861.			
	5,810,043	Entered.		
	4,478,260	Cleared.	3,222,720	
	10,288,303	Total.		
Proportion. 10½ to 16½	1899.			Proportion. 10½ to 18½.
	7,091,125	Entered.		
	9,437,950	Cleared.	6,124,856	
	16,529,075	Total.		

That is to say, the population is increasing more rapidly than the port import and export trade in the above proportions, and shows a deduction of, say, one-fifth in 28 years, or of one-fourth in 35 years—the number of years from 1906 to 1941.

The present import and export trade of the Port being 32 million tons, we must multiply this by two for increase of population, and deduct one-fourth from the result for increase of deliveries into London by rail, &c. This gives the probable tonnage of shipping entering and clearing in 1941 at 48 million tons, *i.e.*, of vessels of 45 tons and over now paying port dues, and we may take the smaller vessels and craft at a similar proportion.

The general result will give less than double the present river traffic in 1941. By that date it is certain that many changes and economies will have been invented and effected which will affect the whole mode of ocean transit, and may involve new apparatus to deal with it in many ways. It may, therefore, be fairly inferred that the capacity of the locks for dealing with the river traffic should be equal to twice the present traffic, or that they should be so constructed that they may be capable of extension to that amount in 35 years, which, according to the above calculation, will provide for all contingencies up to the year 1941.

The calculations here given show that this estimated increase has been fully provided for.

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THE CHARLES RIVER, BOSTON, U.S.A., LOW WATER.

[*To face p.* 61.]

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SECTION XII.

THE CHARLES RIVER DAM, BOSTON, U.S.A.

By D. Urquhart, Thames Iron Works, Canning Town.

Although the construction of dams or weirs in non-tidal rivers is of common occurrence, and numerous examples are to be found throughout Europe, in India, and Egypt, damming a tidal river involves many questions which do not enter into the considerations governing non-tidal dams, and it is unfortunate that no sufficient parallel example of a tidal dam exists from which experience might deduce the necessary data to enable the engineer to provide for and calculate the requisite conditions under which such a dam might be successfully constructed.

The nearest approaches to tidal dams which are in existence are the dams at Netham, on the Avon at Bristol, at Boston on the River Witham, and at Tewkesbury Ham on the River Severn. (*See* p. 78.)

Sir Guilford Molesworth says (Presidential Address to the Inst. C.E., 1905) :—

Deltaic irrigation has been carried out under very favourable conditions on the East Coast of India, the principal rivers being those of the Godavari, the Kistna, and the Cauvery. These rivers range between 350 and 700 miles in length, and drain an area of about 300,000 square miles. Their water is held up at the head of each delta by headworks, consisting of low weirs, with scouring sluices and also regulating sluices, which admit the water to canals radiating over the delta.

The construction of the Grand Anicut, or dam, across the River Cauvery is said to date from the 2nd century. It was restored by Sir Arthur Cotton in 1836 at a cost of £150,000, and now brings in to Government a revenue of £66,000. Sir Arthur Cotton also designed the great works of the Kistna and Godavari deltas which irrigate more than 1 million acres.

In a non-tidal river the current—of fresh water—is always running down; it varies with the weather, often to a remarkable extent. The object of the dam is usually to maintain a certain navigable depth above it at seasons when the river would otherwise be low and even dry, or for irrigation.

In a tidal river, however, the current changes four times a day; the up tide scours up river and the ebb scours down. The natural flow of the river is generally only a fraction of the tidal flow, and has to provide the excess flow on the ebb which is the resultant scouring factor to remove the river sediment and carry it to the sea. But for the upland flow of fresh water the tidal river would be merely an oscillating firth or inlet.

Proposals have been made from time to time by engineers to dam important tidal rivers, but none have hitherto been given effect to until recently on the Charles River at Boston, where the conditions form a close parallel to those to be met with in the Thames.

In 1755 Smeaton proposed the dockisation of the River Clyde as a means of providing a sufficient depth of water for the increasing trade of the Port of Glasgow. His plan was rejected, and the Clyde Trustees have since expended £7,430,000 in dredging and improving the river to a low-water depth of 20 feet, and now spend annually a large sum in maintaining this depth.

Thos. Howard proposed the dockisation of the Avon at Avonmouth in 1877 to provide a sufficient depth of water for vessels passing to the Bristol Docks up and

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down the Avon, there being a rise and fall of tide in the Severn of nearly 40 feet. His proposal was not adopted, because the extraordinary range of tide would have left the
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Improvement Commission was appointed in 1891 and submitted two Reports. A Joint Board was appointed in 1893, and recommended the building of a dam; and public hearings were held by the Harbour Board and Land Commission, who reported that on the evidence before them and imperfect information, they could not recommend a dam. In 1898 an Act was passed authorising its construction, but no action was taken. In 1901 the Legislature appointed a Committee on the Charles River Dam to take full expert evidence on the subject, and since that date an Act has been passed and the works are nearing completion.

The Report of this Committee is of the greatest value as a contribution to river hydraulics and purification, being a very full and voluminous one on all the questions which enter into the proposal to dam a tidal river, involving lengthy and experimental studies of each question by the best experts; and it is not too much to say that the Report is in many senses a monumental one, creating practically a new era in our knowledge of river hydraulics and sanitation.

The Committee undertook to investigate the following questions :—

(1) The existing condition of the harbour and river.
(2) The forces acting to improve or injure it.
(3) The effect of a dam upon these forces.
(4) The causes of shoalings in the estuary, and whether the currents abrade the bottom, moving it from place to place.
(5) Physical examination of the river and bottom, and microscopical and chemical examinations of the material comprising the bottom.
(6) The effect of salt water in the river as to cooling the air in summer, and as to its effect on the natural bacterial purification of the river.
(7) The quantity of sewage discharged into the Charles River.
(8) The effect of a dam on the flow of the tides and upon the health of the district.
(9) Can the dockised basin be kept reasonably sweet and clean ?
(10) Can it be maintained with advantage to the sanitary interests of those who live on its banks ?
(11) Will such a basin be prejudicial to the great interests of Boston Harbour or to possible commercial interests in the Charles River ?

The Report is a very full and careful investigation of all these points, and its findings, so far as they interest us, may be briefly summarised thus :—

(1) The effect of a dam will be beneficial rather than otherwise in all the interests and matters referred to in the queries above.

As to the sewage question :—

(2) That fresh water, gallon for gallon, disposes in a normal manner of more sewage than salt water, salt water tending to precipitate sewage as sludge to the bottom.
(3) That for the proper disposal of sewage in water it is essential that the water be well supplied with oxygen, which is accomplished by contact of its surface with the air, the circulation being effected by waves and

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currents, and especially by the vertical movement caused by changes of temperature. Bodies of fresh, nearly still water, are in this way well oxygenated to a depth of 25 feet in summer and to a much greater depth in winter.

(4) Letting in salt water under the fresh (salt water is heavier than fresh) interferes with the vertical circulation, and such salt water soon loses its oxygen if waste material is added to it, such as sewage. (This shows that salt water, mingling with a fresh-water river, retards instead of assists in natural purification.) The salt water remains below the fresh, loses all its oxygen, and rapidly precipitates sewage sludge, in a state of fermentation, with anaërobic bacteria, and emits nauseous gases.

(5) A comparatively still body of fresh water will dispose of a considerable amount of sewage, admitted from time to time, and will tend to purify itself, even if no more fresh water is added.

(6) Such a body of fresh water will dispose of its sewage better if comparatively still than if in motion. "It is not running water, but quiet water, which soonest purifies itself."

(7) "It is the unanimous opinion of the engineers and experts of the Committee that a fresh-water basin, owing to its supply of oxygen and large area, would not affect injuriously the health of the inhabitants."

(8) "The water in the estuary of the Charles River surges back and forth, day after day, and only gradually finds its way to the sea."

(9) It is not true that salt water lowers the temperature of the air in the territory adjacent to the river, and the substitution of fresh water would have no effect upon the temperature of the air, this being determined by the direction and force of the prevailing winds.

(10) Another most important theory, that of the "seaward gain" of the currents in the proportions of the tidal movements as 5 to 3—stated thus:—"Except for the tides hurrying through this avenue, the present good depth of water could not be maintained"—is negatived by the Committee in these words: "It is true there is a seaward gain of the currents as measured near the surface though the proportion of 5 to 3 is not established; but measured from the bottom, where the erosion takes place, the gain is not seaward but landward," which is explained by the fact that, with a flood tide, the cold and heavier salt water dips under the warmer and brackish water and keeps nearer the bottom.

(11) "It is the opinion of the Committee, and also of those who are interested in the river traffic, that the maintenance of a permanent water-level at the elevation of mean high tide would be a material benefit to owners of wharf property above the dam," by the ability of vessels to reach the wharves at any hour, and to lie afloat instead of risking straining their hulls by lying aground.

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(12) Miles of shore-line of the river will provide ample space for a great development of manufactures, and with this will come an increased commerce by water.

(13) "A probable large increase in valuation of marginal lands."

The value and appositeness of the foregoing authoritative statements as applied to the Thames will be apparent to the reader, and show that popular beliefs and opinions are not to be relied upon in matters of this kind, and that investigation, patient experiment, and observation of experts, have negatived several pet theories of non-experts, notably in the points dealt with in Nos. 2, 4, 5, 9 and 10 of the above findings of the Committee.

Many of the points raised and decided in the Report of the Committee, are dealt with in the Sections dealing with the Tidal River (p. 25), the Sanitary Question (p. 114), the Trade of the Port (p. 121), but there are some notable results that apply to all tidal rivers, and which differ so considerably from commonly-received opinions as to deserve especial attention. We refer to Nos. 2, 3, 4, 5, 6, 7, 9 and 10 of the findings of the Committee, which we will deal with in their order.

No. 2. That fresh water, gallon for gallon, disposes in a normal manner of more sewage than salt water, &c.—This means, of course, that a fresh-water river can oxygenate and neutralize more sewage pollution than a salt one; or, that the fresh upper waters of a river are better suited to dispose of sewage pollution than the salt tidal waters, which latter tend to deposit it as mud on the bottom. But the common idea is that the salt in the sea water has a purifying action of some kind, probably from the practice of salting provisions to preserve them, or from the effort of all sanitary authorities to convey their sewage to the sea as directly as possible.

In proof of this superiority of fresh water over salt water a very extensive series of experiments was carried out on both waters under exactly similar conditions, and to which various volumes of sewage were added; and other experiments were made in a similar way, using mud polluted with sewage, which gave similar results in favour of the fresh water.

* Many persons have the idea that a salt-water basin is more healthy, and that the mere presence of salt in the water of the basin would tend to prevent or retard the decay of any putrescent matter that might enter it. But a preliminary study soon led me to conclusions so different from the popular view, as expressed above, that I requested the pathologist, the biologist, and the chemist each to take up this question from his own field of view, and to make his investigations independently of his associates. Each of these experts reported that, in his opinion, "the fresh-water basin would prove the better." In each case the results of large series of experiments proved that "salt in the water had a strong influence as a precipitant of such matters as Charles River mud and sewage pollution, concentrates the polluting particles into sludge banks, which are less easily acted upon by bacteria or other growths which produce inoffensive or odourless decompositions."* In all these comparative experiments with fresh water and salt water, the salt water mixtures produced the most offensive smells.

* Report (p. 76) of John R. Freeman, Chief Engineer, Charles River Committee.

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The Biologist's (Hiram F. Mills) Report contains the following (p. 316) :—

It further appears to me that the occasional introduction of salt water into the proposed fresh-water basin is something which ought to be avoided. The reason for this is, that it would probably cause the death of the delicate fresh-water organisms that would come into contact with this salt water, and also because its greater weight would tend to hold this salt water at the bottom, and vertical circulation would be interfered with, so that it could obtain little, if any, fresh oxygen from the surface, with the result that the well-known phenomena of putrefaction would follow.

"BACTERIAL PURIFICATION" (John R. Freeman, C.E.) :—

This process (referred to in Section XVIII) is substantially the same as that by which the manure applied to the lawn or garden is made inoffensive; and is the same process on which the most efficient modern methods of purification of sewage and purification of water supply are based.

This process begins with bacterial action. These low forms of life, of which from 1,000 to 50,000 individuals are found in each teaspoonful of the water of the upland Charles River, seize on this pollution as their natural nourishment; or, speaking as a chemist, they oxidise it, nitrify it, break it up chemically, and transform it into new compounds of different chemical composition, which are directly available for plant food; and on these, secondary compounds, the algæ, microscopic plants and plants of larger growth find their nourishment: these in turn give food to multitudes of microscopic organisms, crustaceans and others, barely visible to the naked eye, which in turn become food for larger organisms and minute fishes. These plant growths are also browsed upon by the vegetarian fishes, which in turn furnish food for the larger carnivorous fishes.

Dr. Samuel Rideal (London), in his work on "Sewage and the Bacterial Purification of Sewage," 1901, pp. 14-18, speaks of the well-ascertained fact that the bacteria, always naturally abundant in river water, are able by the aid of the oxygen dissolved from the air to oxidise more or less rapidly any ammonia or organic matter that may be present.

He quotes Dr. Dupre as stating that, "on the average a dilution of sewage by 30 volumes of thoroughly aerated river water prevents it from fouling and ultimately purifies it."

The River Exe has a volume of upland flow 40 times the volume of the sewage discharged into it with no chemical evidence of pollution a few miles below.

Mr. Goodenough found that "where the degree of dilution exceeds six cubic feet per second per 1,000 persons, objectionable conditions have not been produced."

This in the case of the Thames would correspond with (population 6 millions), 6,000 x 6 = 36,000 cubic feet per second, divided by the difference in intensity of effluent as compared with raw sewage, or about 36 to 1 = 1,000 cubic feet per second upland flow required, or 86 million cubic feet per day, the average upland flow of the Thames being 156,142,000 cubic feet per day, about twice the required quantity; besides which is to be added the enormous oxidation during its progress down the river described in Section XVIII :—

Out of 36 Massachusetts streams reported upon by the Sanitary Engineer (Goodenough), 13 receive and digest without offence a larger percentage of sewage than it appears that the proposed Charles River basin could possibly receive from sewage, street wash, and all other sources that can be foreseen.

AND AS TO STAGNATION.

The words, "a basin of stagnant water," have been used by some of the opponents in a way that appeals to popular prejudice and not to modern science. Modern science has reversed the tenet of 30 years ago, and now unhesitatingly affirms that it is quiet water rather than running water that purifies itself.

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Mr. Goodenough's conclusion from his experiences with ponds at Easthampton, Attleborough, and elsewhere, is that sewage discharged into a pond or slow-moving stream, such as the proposed Charles River basin, has a less noticeable effect than an equal volume of sewage has upon a rapidly-moving stream of equal volume.

Effect of Sea Water on Sewage.

A valuable contribution to our knowledge of the action of the saline constituents of sea water on sewage matters was presented by Messrs. Purvis and Coleman to the Sanitary Congress at Bristol, and is published in the current issue of the *Journal of the Royal Sanitary Institute*. It was found in the course of the authors' experiments that a solution of sodium chloride seemed at first to favour the production of free and albuminoid ammonia from sewage, but the process did not go far and neither nitrates nor nitrites appeared, nor was the action of the magnesium sulphate and magnesium chloride more effective, but the mixture of these salts in their respective relative percentages was more marked. It is stated that one of the most striking effects of the salts in solution, both singly and when mixed in the proportions in which they occur in sea water, and also of the natural sea water, both sterilised and unsterilised, was in the interference in the production of nitrates and nitrites. The general result of these experiments tends to prove that to pour sewage directly into the sea or an estuary is essentially unsound. The intolerable smell produced appears to be due to an incomplete and slow oxidation of the various organic compounds in the sewage. There may also be interference with the growth of the useful nitrifying organisms which would normally and rapidly convert the material into non-odorous and neutral substances, such as nitrates. The authors consider that before sewage is discharged into the sea it should first be treated by some filtration or bacterial or other process.—The *Times* Engineering Supplement, Wednesday, September 26th, 1906.

The obvious conclusion to be drawn from this important pronouncement is that in the case of the Thames, the sewage matters should be subjected to bacterial action in the fresh water of the river unmixed with salt water, and, if possible, the complete oxidation or nitrification of the sewage matters completed before reaching the salt water of the estuary.

It follows further that a large proportion of the estuary deposit is unreduced sewage precipitated by the salt water, which is carried up and down the river by the tides, and that the purification of the estuary foreshores will only be effected by the foregoing method of reduction in the proposed fresh-water non-tidal river, held up by a dam at Gravesend.

This purification of the estuary foreshores means the complete regeneration of the seaside resorts situated on its shores, all of which are beset with Thames mud deposited on the shores of the estuary.

No. 3. Similar series of experiments and open examination of fresh-water ponds and streams confirmed the view that still fresh water absorbs oxygen quite as freely and rapidly as that in rapid motion, as in a running brook, this result being due to the vertical circulation always going on in any body of water, caused by changes of temperature or difference of temperature of the water and air. This view is manifestly contrary to the popular one that running water is the freshest and best aerated.

No. 4. The fact that salt water ascending a river from the sea with the flood tide to a great extent slides under the fresher water which descended on the last ebb is generally well known. This is due to its greater specific gravity and sometimes a lower temperature.

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It used to be the practice in the River Thames for seamen to fill their water casks from the river, and they found it necessary to use only the surface water, for at 2 or 3 feet below the surface it became brackish. (*See* p. 27.)

In the Colne and other rivers the writer has found that the descending fresh water keeps to the surface, floating above the salter water, and it must be evident that for free vertical circulation of the water, so necessary for its oxidation by contact with air, such differences of specific gravity must exert a greatly retarding influence.

The diagram, Fig. 26, from the Charles River, shows the varying salinity of the water at different depths and states of the tide.

No. 5. A comparatively still body of fresh water will dispose of a considerable amount of sewage, admitted from time to time, &c.—These propositions also do not immediately appeal to the commonly-accepted ideas of the general public, but have only in recent years become established facts. A long series of experiments on

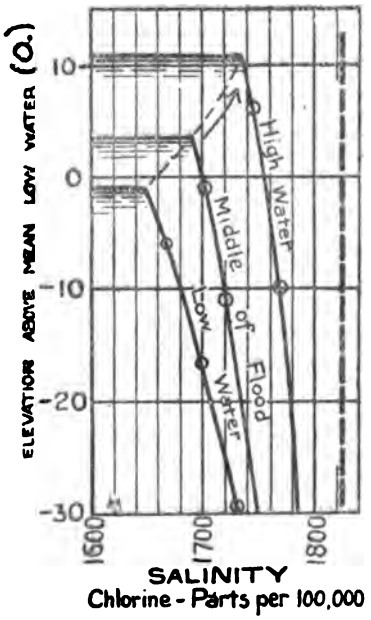

Fig. 26.

quantities of still fresh water in vessels to which sewage was added in gradually increasing volume, proved conclusively both statements. Comparative tests in the same way were made with still water *versus* running or dripping water with like results. (*See* further on this subject, Section XVIII.)

No. 7. That a fresh-water basin would not affect injuriously the health of the inhabitants.—This simply confirms—as a necessary corollary to the foregoing points—the fact that a comparatively still water basin of fresh water cannot be more detrimental to public health than a mixed tidal river. The state of aeration of the still water will be at least as good as with the tide water, with the additional advantage that the mud banks will not be exposed twice daily, nor the discharged pollution returned up river every tide to pollute the air.

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VELOCITY OF TIDAL CURRENTS IN BOSTON HARBOR

SECTION C-D

VELOCITIES IN VERTICAL PLANE
ON EASTERLY SIDE OF CHANNEL
AT VARIOUS STAGES OF TIDE
Observed by Current Meters.

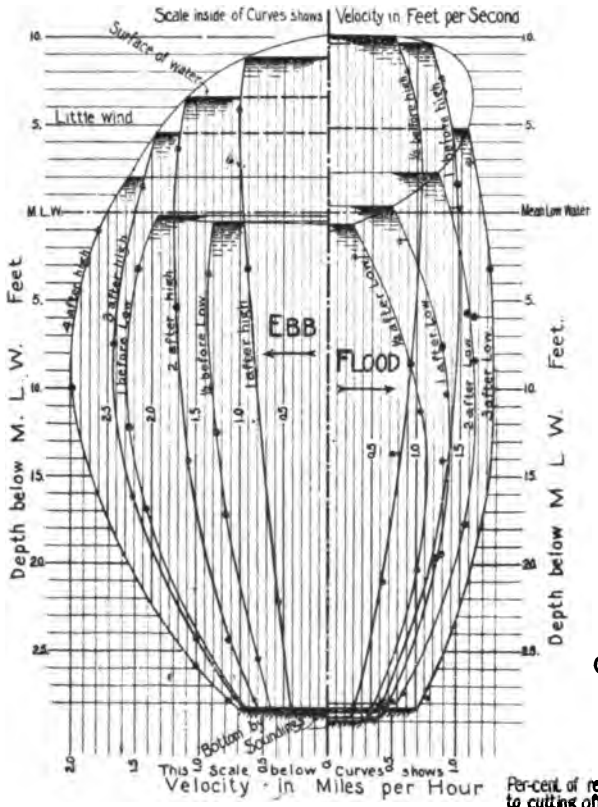
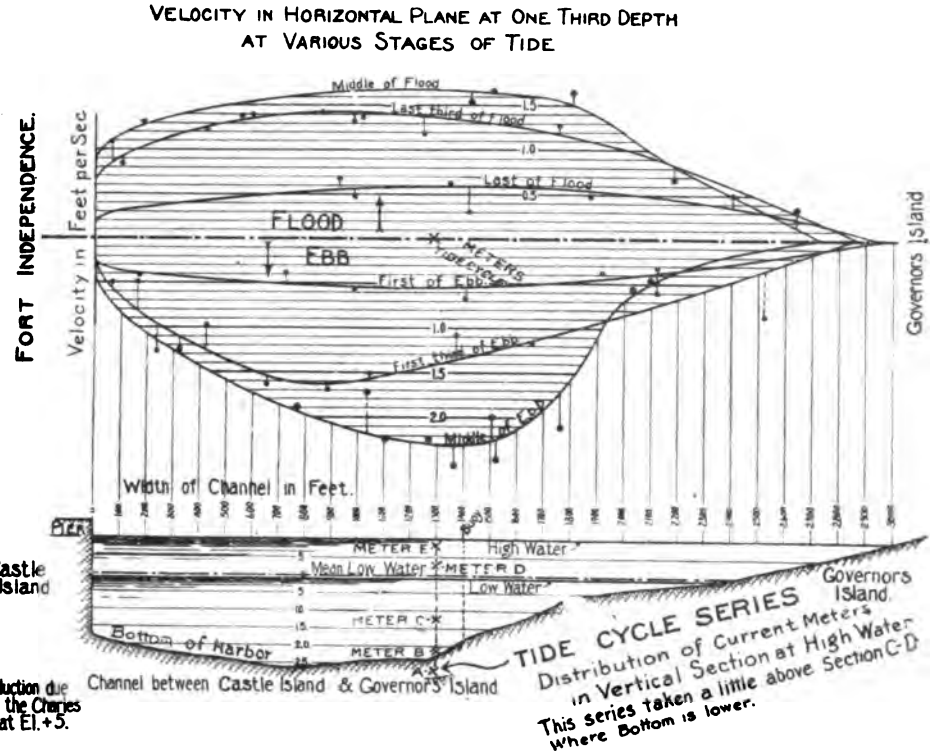

Scale inside of Curves shows Velocity in Feet per Second
Surface of water
Little wind
M.L.W.
Mean Low Water
EBB
FLOOD
Depth below M. L. W. Feet.
Depth below M L W. Feet.
Bottom by Soundings
This Scale below Curves shows Velocity in Miles per Hour

Fig. 27.



Per-cent of reduction due to cutting off the Charles River – 18.5 at El. +5.

Fig. 28.

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No. 9. That salt water ascending with the tide does not lower the temperature of the air in the territory adjacent to the river:—though a minor point of little importance in the Thames at London, was of greater value at Boston on account of the heat of summer time, and it was contended that the cooler sea water had an effect in lowering the temperature of the air in summer. But, like the parallel suggestion of the average Londoner, sometimes expressed in the Press, that the salt water in the Thames flood tide brings up the aroma of the ocean with it (*see* p. 144), or the equally visionary idea that the rise and fall of the tide keeps the air over the river in circulation (*see* p. 144), this romance must, with regrets, be relegated to the pages of fiction and fancy.

No. 10. Seaward gain of currents: This subject needs treating at some length, inasmuch as some ancient and highly-respectable engineering theories are in dispute. This theory is simply that the ebb current removes to sea more silt than the flood current brings up. But this theory has often been disputed, though it does not necessarily apply to every tidal river. In the Thames the average floods flow 5½ hours and ebb 6½ hours, but the speed of the currents is in a different proportion; for the average speed of the flood tide is 2¼ miles per hour and of the ebb 2 miles per hour, the latter varying somewhat with the variation of volume of the upland water. From this it is evident that the flood tide—though shorter in duration, and forming a volume of water lesser than the ebb by the amount of the upland flow—yet has a swifter flow, and therefore a more abrading current, which may, and in the case of the Charles River does, move more silt from the bottom than the longer-flowing but slower-moving ebb.

Extensive experiments were conducted and recorded as to the relative rapidity of the current at the surface and at other depths to the bottom in the Charles River, which show, as might have been expected, that the bottom velocity is much less than at the surface; and as it is the former which must be the abrading current, it is evident that in any river it is useless to assume results calculated on the surface velocity unless a considerable deduction is made for depth.

The diagrams, Figs. 27 and 28, show the curves of velocities at various times and levels of surface during ebb and flood as a mean of a large number taken under all conditions. From these it is evident that the most rapid current is at from one-third to one-half the depth below the surface. Fig. 27 shows the changes of velocity during the continuance of ebb and flood. Calculation of the bottom velocities of ebb and flood compared from such sections shows abrading power in favour of the flood tides. The results are thus summarised:—

(1) The flood tide comes in first on the bottom.

(2) The tide turns from 10 to 20 minutes earlier from ebb to flood close to the bottom than at the surface.

(3) The balance of scouring effect is in favour of the flood tide.

Similar series of experiments have been made in the tidal Avon, and, as the general circumstances of both rivers are similar, the results are practically the same. Mr. W. R. Browne, M.A., M.Inst.C.E., in a paper read before the Institute of Civil Engineers in 1881 (Vol. LXVI.), on "The Relative Value of Upland and Tidal Flow,"

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records a number of measurements made by him and other well-known engineers in the River Avon at Bristol, in which the difference between the surface and bottom velocities is much greater than in the Charles River. These show that while the surface velocity was as much as 3 to 4 feet per second, the bottom velocity was often *nil* and seldom rose to half that of the surface. Similar experiments made in the Connecticut River, U.S.A., by General Ellis in 1878, and quoted by Mr. Browne, gave practically similar results, and are also confirmed by M. Révy in his "Hydraulics of Great Rivers"; and in the Report to the King of Holland on Dutch Public Works, similar tests were made in the Rhine and Meuse with the same results.

The general purport of all these results is to prove that bottom velocities are seldom sufficient to abrade the bottom, and that such abrasion only occurs in exceptional tidal currents, whether from spring tides or heavy freshets.

Du Buat's experiments on erosion of river bottoms gave the following results :—

Potter's clay is abraded by a current of			·26	feet	per second.
Sand deposited by clay	,,	,,	·54	,,	,,
Large angular sand	,,	,,	·71	,,	,,
Gravel, size of peas	,,	,,	·53	,,	,,
Gravel, size of beans	,,	,,	1·07	,,	,,
Round pebbles, size of a thumb		,,	2·13	,,	,,
Angular flints, size of an egg		,,	3·20	,,	,,

The velocity of the Thames at London on a flood tide was found to be 3 feet per second at the surface, which would correspond with about 1 foot at the bottom. The fact that mud lies on all the Thames bottom, except on projecting areas, shows that the bottom velocity must be very small and generally insufficient to erode it, although it is a softer material than potter's clay.

* Experiments made by Mr. L. P. Vernon Harcourt, and described in a Paper read before the Institution of Civil Engineers, 1900, on the relative powers of fresh river and of sea water to deposit silt in the formation of banks and bars, show, in general, a marked rapidity of deposit in the salt water as compared with river water.

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RIVER WALL SUBSIDENCES AT BARKING, RESULTING FROM DREDGING IN THE RIVER. THE PILES HAVE BEEN FORCED OUTWARDS BY THE SLIDING OF THE EARTHWORK INTO THE RIVER.

RIVER WALL SUBSIDENCES AT BARKING RESULTING FROM DREDGING IN THE RIVER ABOUT 150 YARDS FROM THE WALL.

[*To face p. 71*]

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SECTION XIII.

DREDGING AS A MODE OF DEEPENING THE RIVER CHANNEL.

The Thames Conservancy Board has for many years exercised its powers of dredging the bed of the river, and has supplemented this by licensing private dredgers to excavate the river bottom.

The material dredged, however, is either mud or gravel; no dredging is attempted in the chalk.

The usual and presumed object of dredging is the removal of shoals or sandbanks and accumulation of mud, which constitute legitimate works of maintenance. It is, however, certain that the private dredgers dredge for gravel to be sold as ballast or for building purposes, and that the material fetches a good price, so that these dredgers do not work on materials that are unsaleable.

This policy is not calculated to improve the river bottom, but rather tends to cut it up into holes, leaving untouched banks that ought to be removed and creating holes where they are not desirable.

Further than this, it unseals the river bottom, allowing the salt water to penetrate to neighbouring wells; and, in some instances, where the dredging has been too near the foreshores, the river walls have suffered by settlement or collapse.

From long continued but desultory dredging of this kind, never taken to more than a few feet in depth, the opinion seems to have grown that extensive dredging out of a deep channel in the middle of the river is quite practicable, and this idea has been tacitly adopted as the basis of the proposals for improvement of the Port of London, which have been embodied in the various Port of London Bills.

It is most unfortunate that this proposal was thus tacitly assumed as practicable by the Port of London Commission, and no direct evidence taken as to its soundness. No witnesses were called specially to prove its practicability, although several witnesses spoke on the subject and uttered very significant warnings or made important reservations, as will be seen from the following extracts from the evidence given on this point, which were sufficiently alarming to have warranted further investigation :—

MINUTES OF EVIDENCE TAKEN BEFORE THE ROYAL COMMISSION ON THE PORT OF LONDON.

Page 13. (338). Mr. C. J. More, Engineer to the Thames Conservancy Board.

I think I may say at once I do not think a 30-feet channel might be taken up to London, but it might be taken up to Gravesend. If you spent sufficient money, I have no doubt you could get a 30-feet channel up to Gravesend.

(345).—(*Q.*) Above Gravesend there may possibly be some complications affecting the feasibility of any serious deepening of the river, by reason of valuable properties in places bordering its banks, and there may be questions as to the stability of the embankments which protect low-lying lands from being overflowed. These matters would require careful examination; but we have not investigated them, as the upper reaches of the river are beyond the limits of our reference. Have you ever investigated that point?—(*A.*) Yes. That is the question, of course, that would arise

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very seriously. I do not think, until you get a considerable way up the river, there would be much in that; but when you get towards the upper reaches, of course 30 feet is a very great depth to go to.

(346).—(CHAIRMAN). (*Q.*) To what limit higher than Gravesend would you go?—(*A.*) When you come to Woolwich, as a matter of fact, you cannot maintain anything more than about 14 feet, or 15 feet—15 feet is about the most you can maintain through that reach.

(347).—(*Q.*) But up to the Albert Dock entrance?—(*A.*) Yes. I think you could get it there without endangering the banks.

Page 43. (881).—Mr. H. C. BAGGALLAY, Engineer to the London and India Docks Company.

I am afraid that if we deepened the river down below and stopped suddenly at the Albert Dock, the check to the tide would be something like as at Chepstow—the tide would go up suddenly and flood the banks.

Page 52. (994.)—Mr. F. E. DUCKHAM, Engineer to the Millwall Dock.

Of course, many things have to be taken into consideration. The river bed now has formed itself to its natural slope. If you dredged a channel 10 feet deeper than the present channel you might possibly bring down the foreshore on the two sides, and so get into difficulty with the wharves.

Page 144. (3061). Sir A. R. BINNIE, Engineer to the London County Council.

(*Q.*) It was indicated by some witnesses—I think by the Chairman of the Thames Conservancy—that some of the embankments were in a dangerous condition, and might be endangered by deeper dredging; and also that some of the wharfingers might object. Dealing first of all with the old earthen embankments below the Albert Dock, are you quite satisfied that there is very little in that?—(*A.*) I do not think there is any fear on that score below the Albert Dock.

(3,063).—Portions of the river banks in the neighbourhood of North Woolwich and between it and Blackwall are, in places, of a nature to require careful consideration before the maximum depth to which the river can be dredged can be ascertained.

(3,064).—But I have prepared a series of cross-sections showing what might be done if the banks are considered sufficiently stable.

Page 145. (3,069). Sir A. R. BINNIE.

(Sir JOHN WOOLFE-BARRY).—(*Q.*) I suppose you admit that the question of the properties adjoining would have to be studied very carefully?—(*A.*) Very carefully indeed.

(3,070).—(*Q.*) They might have to be protected?—(*A.*) They might.

(3,078).—(*Q.*) Would you advocate a depth of water 30 feet from the Albert Docks right up to the Surrey Commercial Docks?—(*A.*) I should like to see it, but I could not advocate it at present, until, as I told Sir John, there has been very careful investigation of the river to see whether it is possible. I believe it to be possible, but without careful investigation I should not like to say for certain.

(3,084).—The difficulty really I think myself does not exist in the chalk at all, but in the sands and clays of the Woolwich and Reading beds, which immediately overlie the chalk. We met with them in the Blackwall Tunnel, for instance. Some of those sands, when charged with water, partake of the character of a quicksand, and that is where investigation would be required above the Albert Docks to see that we did not plunge into one of these quicksands and bring in the banks of the river. I do not think it is the banks of the river qua banks that would be injured, but the foundation might slip away, owing to the dredging.

Page 146. (3,120).—(*Q.*) Do you think there would necessarily or probably be any continuous dredging to maintain that depth of water if it were once afforded?—(*A.*) As in all tidal rivers you would always have to keep dredgers at work at different points.

Page 354. (6,771). Mr. H. C. BAGGALLAY.

To accommodate ships drawing 30 feet, therefore, the river bed must be dredged to 52 feet below Trinity high water, and this dredging would have to be carried out at once for the whole

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SUBSIDENCE OF QUAY AT BOULOGNE CAUSED BY DREDGING.

SUBSIDENCE OF QUAY AT BOULOGNE CAUSED BY DREDGING.

[To face p. 72.]

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distance from Galleons to beyond Purfleet, about ten miles, and for the whole width of the river to high-water mark in those portions of the river in which it may be intended to construct the wharves. Even supposing this were done, it would be quite impossible to keep a berth in front of these wharves free from mud if dredged below the general surface. The Dock Company know this from their futile attempts at Galleons, Royal Albert Dock. But, apart from the dredging, which would be almost a prohibitive expense, the quay walls would cost three times the cost of quay walls in a dock, even if they could be built without cofferdams. To increase the sectional area of the river to such an extent as this proposal contemplates, might have very serious effects on the river banks through London. The Thames Embankment and the Houses of Parliament would probably be flooded, as it would be impossible to increase the sectional area of the river above London Bridge.

Page 355. (6,772.) Mr. H. C. BAGGALLAY.

(*Q.*) Have you anything to add to that?—(*A.*) There is one point which I think is not quite clear. That is about my fear of widening and deepening the river too much, causing floods in the upper reaches. That would not apply to merely deepening the channel; but I am very much afraid that if you had quays by the side of the river it would be necessary to make the river so wide and deep that if you had a large body of water coming up we should have all our quays flooded. Nowadays we have sometimes to put clay round the quays at the spring tides to prevent the water coming over. An extra foot of water would be very serious. In the London Docks we have to put iron kerbs round the quays 18 ins. high to prevent the flood coming over the quays; and when the Thames Embankment was made they had to put little blocks of stone against the balustrades to prevent the water coming over.

Page 558. (11,504). Mr. A. C. HURTZIG.

(*Q.*) The evidence, I take it, that you wish to lay before us is that certain protection ought to be given to riparian owners?—(*A.*) Yes. The owners on both sides of the Thames think it possible that damage may be done to them from any action which may follow the decision of this Commission, and they wish the Commissioners to be acquainted beforehand with the dangers they apprehend, and to provide for their protection when the time comes.

On p. 22 it has been shown that the Thames bottom has been formed by its volume and current acting upon the material of the beds in which its channel has been cut to a certain angle of stability. To deepen the river without widening it will steepen this angle and make it unstable. The tendency of the current will be to fill up the artificial channel to the original contour, by washing into it the foreshores; thus rendering continuous dredging necessary and weakening the support of the river walls, which extend for many miles along the Essex and Kent shores, and protect the low-lying lands from flooding.

During the past year dredging for the purpose of deepening the channel has been carried on at Blackwall and elsewhere under the direction of the Thames Conservancy Board. The depths gained have only been some 3 or 4 feet, but it has been found that the channel so made cannot be maintained, and the adjoining walls have settled several feet in places.

The following extracts are from a letter in the *City Press*, of September 3rd last, signed "John Hollway."

The river wall (part of the Havering Commissioners Ripple Level) which adjoins land belonging to Laws' Chemical Works, Barking, is steadily sinking, causing those who have to maintain that part of the wall a large and continuous outlay. (*See* photographs.)

Large quantities of sand are to be found just opposite to where the wall is sinking, and the sand works out from under the wall, and is the cause of the wall sinking at that point. By

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preventing the sand barges from dredging in front of the sinking river walls the Thames Conservancy tacitly admits that such dredging causes damage, but, unfortunately, the serious damage is continued by the Conservators own dredging, in order to deepen the channel.

This being so, and the walls sinking at Barking, where there are no buildings erected on the river front—how much greater will be the damage that will be sustained in the upper part of the tidal river unless first properly embanked.

Very considerable damage has also recently followed an attempt to dredge the channel in Boulogne Harbour to a depth of 3 feet. Several hundred yards of the adjoining quays, constructed on masonry walls, have subsided—(*see* photographs)—and will involve a very costly reconstruction.

Similar disasters are very likely to follow any attempt to dredge an artificial deep channel in the Thames, involving the removal of some 15 feet of river bottom, and the consequences might be, in fact, much worse, as the river walls are to a great extent lined with, and the supports of, massive wharf and warehouse buildings, which, as a rule, have no other foundation than the gravel of the foreshores.

All the riparian owners, the Commissioners of Sewers and Levels of Essex and Kent, who keep the walls in repair, are strongly against the dredging proposal, and point out that any serious subsidence of the walls would involve flooding of extensive areas of marsh meadows. Dredging would also greatly reduce the depth of material protecting the crowns of the Thames Tunnels, which might conceivably be destroyed by sunken vessels. For this reason an injunction was obtained against the Thames Conservancy Board, in 1904, from Mr. Justice Farwell, prohibiting dredging over the old Thames Tunnel constructed by Brunel.

Dredging in a tidal river and dredging in an estuary, firth, or inlet are undertakings having little in common, though so long as their work is confined to a mere reduction of banks, or a slight deepening of a wide channel, which does not greatly steepen the angle of repose of the bottom material, dredging may be carried on with considerable certainty as to its results.

In a tidal river, however, having a comparatively narrow channel, in which the current runs the full width at from 2½ to 3 knots, and where the dredging amounts to something more than a scratching of the bottom—where, in fact, the angle of repose may be increased to five or seven degrees, and the sectional volume—and therefore the speed—of current are much augmented, the original stable conditions natural to the river are rendered very unstable.

The increased current, or indeed the normal current, quickly washes down the foreshores into the channel, and the tides rise higher and fall lower than before, owing to the increased volume and momentum; the results are continuous dredging to keep the channel open, and increased danger of floodings from overflows due to high spring tides.

In the Thames this has been proved to be the case in years past. The tides from Blackwall upward now rise 2 to 3 feet higher than they did in 1846, when there was a sort of weir across the river at London Bridge offering obstruction to the tides; also since the construction of the Thames Embankments, which have compressed the tides into a narrower channel than formerly.

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Glasgow and the Clyde provide striking object lessons in the results of dredging a channel for navigation, and emphasise the above contentions, well known to Engineers. In the Clyde, in 1821, the greatest draught was only 13½ feet, increased in 1851 to 18 feet; in 1891, to 23 feet; and in 1900, to 26½ feet—the result of dredging. But the Clyde is an estuary, or firth, rather than a river, in which the dredged channel is only about one-sixth of the width of the waterway, and the rise of the tide, and therefore rapidity of current, smaller than almost anywhere round our coast.

But the results of this dredging upon the volume, current, and rise and fall have been remarkable. Whereas in 1755 Smeaton found the springs at Glasgow rose only 1 foot 9 inches, while the neaps were only just perceptible, in 1858 the springs had increased to 8½ feet and neaps to 6½ feet, and at the present date the springs rise 11½ feet and neaps 9 feet. So that the low-water line has been falling about 9 feet 7 inches since 1755, and is actually lower than at Port Glasgow.

The acceleration of current has, of course, followed in a similar ratio. In 1768 the interval between high water at Port Glasgow and Glasgow was two hours. In 1838 it had shortened to 1 hour 23 minutes, and now it only takes one hour; that is to say, the current is now twice as rapid as in 1768.

Dredging in the Clyde has, therefore, lowered the low-water level 9 feet 7 inches, and increased the rapidity of the current 100 per cent in attaining a low-water depth of 26½ feet.

In this work, extending over 80 years, vast quantities have been dredged from the Clyde channel. The total quantities are not ascertainable, but up to 1897 35 million cubic yards had been deposited in Loch Long, and from March, 1893, to June, 1900, 10 million cubic yards were deposited off Garrock Head.

Silting is constantly going on in the channel, and five dredgers are employed in keeping it clear. The deposit includes the sewage of Glasgow, each million gallons of which produces 40 tons of sludge; so that 1,500 tons of sludge are daily (1902) deposited in the river from the sewage.

Between 1890 and 1900 19,250,000 cubic yards were dredged, consisting of 10,500,000 cubic yards of new material, and 8,750,000 cubic yards of deposit. Between 1844 and 1900 the total quantities dredged amounted to 56,500,000 cubic yards.

Professor Harcourt says that "The depth of the Clyde channel has long ago been carried to an extent which the current is quite unable to maintain . . . . so that each year the channel is becoming more artificial in character and its maintenance more costly. . . . and should be regarded as a channel whose depth has been increased so far beyond its natural limits that it has to be constantly maintained by artificial means."

The abstraction of—or sliding into the channel of—the foreshores has had the effect that might have been anticipated.

* "As the deepening of the river proceeded, the older walls, becoming gradually undermined, were brought down and required to be renewed, while more modern ones

* By W. W. Alston, Esq., Engineer-in-Chief to the Clyde Trustees.

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have had to be strengthened by sheet piling in front and tie rods taken back to blocks of masonry. More recently cylinder and caisson foundations have been adopted generally, and taken down to considerable depths in constructing the walls."

This plan is sound and reliable when properly carried out, but also very costly.

"The Clyde, like the Thames, runs through mixed strata of sand, clay, running sand, gravel, mud, plastic clay, boulder clay and freestone.* Sand and gravel predominate and are highly charged with water."

It is, therefore, fair to assume that a similar deepening of the Thames by dredging may be expected to bring about similar results; with this difference: the Thames has a much greater tidal range, narrower channel and stronger current, and therefore the washing down of the foreshores and consequent injuries to the old embankment walls are likely to be extensive and very costly; and the increase of tidal range—due primarily to the greater natural range in the Thames, and secondly to its greater length and stronger tidal wave—will also in all probability increase the height of spring tides, many of which now overflow the quays and low-lying areas by backing up the main sewers. The low tides will also fall lower than now, reducing the additional depth gained by dredging; and in the upper reaches above the dredged area, where the low-water depth is now only a few feet, it is very likely that during springs the bed of the river will run dry at low water.

These results are merely those foreshadowed by the witnesses referred to above before the Royal Commission on the Port of London.

It will certainly not improve the beauty or amenities of the river above London Bridge to have the bottom exposed twice daily; nor will it permit of navigation of barges, tugs, or passenger steamboats, which often ground now at low water.

There is also the increased danger to navigation arising from the greater velocity of the current, especially round bends and in foggy weather. A vessel, in coming up the river, must do so at a speed in excess of the tide to maintain steerage way and even then is liable to sheer about and become unmanageable. This navigation requires the greatest skill and judgment in the crowded Thames as at present, and with the growing number and size of vessels, the diminished waterway and more rapid current after dredging, must be matter of anxiety for the future.

* There is no freestone in the Thames, but its place may be considered to be occupied by the chalk formation.

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SECTION XIV.

WILL THE RIVER SILT UP BELOW THE DAM?

It has been shown in detail, in the Section on Pollution and Silting (p. 33) that, so far as the upland waters are concerned, and the effect of the accession of sewage effluents and other extraneous matters, deposit must take place in the river lake above the dam; that which, on account of its lightness, is carried over the weirs and sluices will be even less liable to deposit below than above the dam. So that as to silting below the dam, the upland waters may be eliminated from the calculation, and the question becomes narrowed down to one of the effect of the stoppage of the tidal flow on the waters of the estuary, and thus on the deposit and distribution of the sand and mud banks.

On page 31 the volume and currents of the estuary have been considered, and it has been shown that the withdrawal of tidal action will have the following results:— Immediately below the dam there will be practically still water, both on the flood and ebb tides, with no perceptible current either way. When sluicing is going on, or discharging the locks, or when any considerable freshet is coming down the river, and thus an unusual volume of fresh water is passing the sluices, these will produce a slight current down river if the tide is ebbing, but imperceptible if the tide is rising, and locally, in line with the discharging sluices, there will be a current which may—if at low water and the scouring sluices are being used—acquire for the time a velocity of two or three knots per hour or more. But ordinarily and normally there will be a down current of less than 100 feet per hour, and this on the ebb only.

On the flood tide there will be no current worth mentioning or perceptible. But, lower down the river, the conditions will gradually approximate to those now existing; that is to say, the ebb current will increase until at about Leigh it will attain nearly its present speed and time of flow—the flood current slightly less so; and at Sheerness there will be no difference observable between the present conditions and those under discussion.

This can readily be understood, after consideration of what has been advanced on p. 31, where it has been shown that the tidal river water bears a very small proportion to the tidal estuary water.

Silting is the deposit of floating particles in comparatively still or slack water, and in the present case, where the upper river silt is eliminated, these matters must come from the sea or from the estuary and its foreshores.

The sea bottom is known to be chiefly fine sand or sand and mud combined. The foreshores are also partly sand, but very generally are covered with mud; and it is universally admitted that much of this mud is brought down by the river, and is largely London sewage and river drifts. The estuary shores are, however, bordered by marshes and low, alluvial shores, which are being eaten into by the tides and carried away as fine silt, to be deposited in slack water. Some of this now ascends the river and

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mingles with the up river pollution. This source of river mud will clearly cease with the closing of the river. It is also evident that the tidal water below the dam will not be polluted with up river soilage, although the existing pollution of towns on the estuary and the Medway may remain as now.

The absence of tidal movement for some miles below the dam undoubtedly provides the proper condition of the water for deposit of silt, and it is in this area that it may be expected to occur, if at all. But the absence of flow produces also absence of scour; that is to say, in this still water area there will be no washing up of deposits, such as now occurs every tide from the rapidity of the current, and only the eating into the alluvial marshes due to wave action (as apart from tidal action) in windy weather, as a source of silt in this area. This silt cannot be large in quantity, and cannot travel far in the absence of current. It may be, therefore, expected to deposit on the neighbouring foreshores or creeks.

The channels of the upper estuary, therefore, are not likely to be affected materially. They have been formed by the existing tidal action, and will not be reached by water which may be laden with sand from the lower estuary, as is now the case; because the volume of water which passes up the river every tide now from the upper estuary, and which is replaced by an equal quantity from the lower estuary, will cease to flow. There will thus be reduced circulation in the upper estuary, combined with the barring out of the upper river mud and the absence of lower estuary sand silt, which is now liable to be washed up owing to its rapidity of current.

In connection with the Charles River Dam, this question was very fully investigated, and the conclusion was arrived at that silting could not occur. On this question the Report says:—

"The Commission of 1859-66 advanced the fundamental theory that 'were the reservoirs (the rivers leading into the estuary) closed, the larger part of this main artery (the ship channels of Boston upper harbour) would, in course of time, cease to exist, for it is but the trench dug through the yielding bed of the harbour by the passage to and fro of the river and tidal waters.'

"This theory, however, we find to be wholly erroneous."

In the case of the Richmond half-tide dam on the Thames, again the Thames Conservancy Board predicted that it would result in serious silting below, but that Board now states "Its effects upon the *régime* of the river, as a whole, cannot be said to be injurious."

The tidal River Avon, at Bristol, has also been closed by a dam, at Netham, as to which similar prophecies were made, and which also turned out to be erroneous.

The tidal River Witham, at Boston (England), has been closed by the Grand Sluice, and no silting below it has followed.

The Severn is closed by a weir and locks at Gloucester, as to which the engineer (Mr. H. J. Martin) says that, "contrary to expectation, their effect had been to materially improve the velocity of the flood current, so much so, that in one case a portion of the river, nearly three miles in length, had had upwards of 200,000 tons of silt removed from it without any dredging whatever." (Inst. C.E., Vol. 46, p. 77).

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If, however, silting does occur, it becomes a question whether it will be of such extent as to be injurious, and whether it can be removed at a reasonable cost.

Methods of Removal of Silt.

There are at least two ways of removing silt :—(1) Artificial scouring ; (2) Dredging, which includes hydraulic dredging.

The silt will be deposited in the channel or foreshores between Gravesend and Mucking, below this point the current will be sufficient to prevent it ; so that the artificial removal of silt will be confined to one reach of the river about 6 miles long, and in all probability chiefly to the upper end, near Gravesend.

Scouring.

In the closed river it has been shown (p. 25) that there will be always a volume of 107,544,643 tons of water available. But assuming that only the surplus upland water after withdrawal of the locking water is to be used, the quantity available will average 50 million cubic yards per week. Once a week is perhaps the period of greatest frequency of scouring likely to be necessary. Most of this quantity will have to be discharged daily over the sluices, as it cannot be stored in the river ; but at any time from five to ten million cubic yards could be discharged through sluices of proper dimensions in 30 minutes, given a discharge velocity of 1480 feet per minute, which, however, will be rapidly reduced below the dam by the resistance of the volume of salt water to about 420 feet per minute at, say, half a mile below. The discharge should be made during the last hour of the ebb, when the river is low and its cross-section at its minimum.

As to the efficiency of such scouring, we have many examples. Experiments were made in the Avon by the discharge of water from the floating harbour through the underfall, and proved to have a powerful scouring effect about three-quarters of a mile lower down, although the water had to pass two abrupt bends amounting to about 180 degrees. Most dock entrances are kept clear of mud by scouring sluices, and the annual reports frequently allude to their efficiency.

Dredging for Removal of Silt.

It has been shown that if silt is deposited it will be of a fine consistence—not gravelly. In such cases the sand pump dredger will remove enormous quantities with ease. Where there is a sufficient current the hydraulic dredge will stir up the silt in large quantities, allowing it to be carried away by the ebb tide. An ordinary dredger can remove 14,000 tons per day.

But it has been asserted that the lower main channels of the estuary, the Duke of Edinburgh, the Prince's, the Alexandra, the Oaze Deep, West Swin and other channels will be disastrously affected by the closing of the river. As to this, the figures given on p. 31 prove that the effect on the flow and currents in these remote areas will be infinitesimal. Their waters do not reach the river at all, nor does the river water reach them, the tidal travel in the estuary being only about nine miles. An inspection of the map of the estuary (p. 25) shows that their configuration is purely local, and due to local wind and tide currents and the character of the bottom.

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The estuary (*see* map, p. 25) is an area of low lands overflowed by the sea, following the course of a river mouth, and widening it by local action on the shores, in which the current of the river has had no part. The Thames is a mere driblet compared with the estuary, and in this respect resembles the Clyde, the Humber and others, in all of which the estuaries are inlets or conformations of the land in which the rivers are mere incidents, not causes; their channels result from the ebb and flow of the tides, and would be much the same if the rivers ceased to flow or to exist.

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SECTION XV.

ON INFILTRATION FROM THE THAMES.

By CLAYTON BEADLE, F.R.Met.Soc., F.C.S., Secretary to the Underground Water Preservation Association.

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The Report I propose to give on the above subject is primarily for the purpose of ascertaining how much water would, in all likelihood, percolate from the Thames, if the river were permanently held up to high-water mark, as would be the case if the Gravesend Barrage became an accomplished fact.

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With the view of forming some idea on this complex question, I am compelled to review the various conditions which tend to promote or retard infiltration under the existing circumstances, as well as to bring forward any evidence at our disposal to show the presence or absence of Thames water in the neighbourhood of the river.

With a great deal of diffidence, I have at the end of my Report endeavoured to forecast what might be expected to happen under the altered conditions. I venture to suggest that this Report should be regarded as one giving information rather than one from which definite ultimate conclusions should be drawn. It will, I hope, be suggestive by indicating the lines along which further information should be sought.

As to Saturation Levels.

I understand from Mr. Hennell's investigation (*see* Section XVII.) that the river walls are perfectly water-tight, but that they are not built to any depth into the marshes, and that for all practical purposes they may be regarded as having been built on the top of the marsh land. Therefore any permeable strata in the marsh land is not shut off from the river by the wall. My own observations have led me to believe that the natural water level in the marsh land approximately corresponds with the "mean tidal level" in the river. (It is, of course, reduced below this in places by extensive pumping operations.)

I take it, that in order to safeguard present interests, in the event of the Barrage being carried out, the level of the water will not only have to be kept below that of the marsh land, but to the present "saturation levels" (even in times of storm). This means that the water would have to be raised by pumping from the "mean tide level" to "high tide level," or say, 10 feet. This signifies the necessity of permanently maintaining, under all circumstances, a difference in levels of 10 feet between the river and the marsh land. Thus, however rapid the ingress of water under the bank, a difference of 10 feet must be maintained in the levels of the water between the outer and inner side of the wall. I take it that this is a matter of absolute necessity, because so many factories are—or may in future be—located in the low-lying land immediately behind the river wall.

It is quite conceivable that if no pumping were resorted to, to counteract the infiltration, the level of water in the marsh land might ultimately rise to that of the river. The great difficulty is to form some judgment of the amount of water which, under a difference of "saturation levels" of, say, 10 feet, would pass from the bed of the river to the marsh land. This water would probably be fairly constant in quantity, or perhaps a slowly diminishing quantity. I am compelled to go into the various questions which affect this subject at considerable length, as it presents many difficulties and raises questions of extreme complexity.

As to Bare Chalk in Marshes and under the Thames.

As the chalk is the great water-bearing strata in the London basin, and as the subject of the passage of water through chalk has received so much attention, we may, with some advantage, regard the chalk as a possible source of information in tracing the possibility of percolation from the Thames. A band of chalk, either bare or covered with permeable beds, extends through Deptford, turning southwards towards Lewisham,

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then north-east through Greenwich, until it touches the water at Woolwich, for a distance of about three-quarters of a mile. The greater part of its area is covered with permeable beds, and is situated mostly under land which rises above high-water mark. If water rose in this part of the chalk to the high-water level of the Thames, it would not reach the surface of most of this land.

At the foot of the hills and right away to the river wall the ground is covered with "mixed" beds. The chalk extends away from Woolwich to Erith, where it again touches the river; here the sand has been removed for ballast, leaving a large area of more or less bare chalk considerably below the high-water mark, and at a few hundred yards from the river wall.

In these pits the large engineering works of Vickers, Sons & Maxim and Fraser & Chalmers are situated. At the "Garden Wharf," Erith, close to the railway station, there is bare chalk in the river bed, and I believe also higher up the river.

There is a "fault," the edge of which, I believe, is traced close by the Board Schools at Erith, and "faults" are known to have a marked effect on the flow of water, either to increase or decrease the flow, according to circumstances. The probable effects of these "faults," which occur in the bed of the river would have to be arrived at with the assistance of some geologist who is well acquainted with the district.

There is chalk in the bed of the river at Chalk Farm, Erith, and solid chalk at the "Garden Wharf." Many feet of this latter had to be removed to deepen the berths for the colliers that discharge at Beadle's Wharf. The piles of Erith Pier extension were driven into solid chalk. In front of the Erith Foundry (formerly Easton and Andersons) there was a promontory of chalk which was removed to make a wharf there. The chalk passes under the river and touches at Purfleet, Greenhithe and Gravesend, for a distance of about 2½ miles.

Between Northfleet and Gravesend, and elsewhere in the neighbourhood of the river, large masses of the upper chalk have been removed for cement making; in fact, the removal of the chalk has been taken close down to the "saturation level," *i.e.*, "mean tidal level," or a few feet above it. Enormous quantities of water have to be pumped to reduce the "saturation levels," and make the lower chalk workable; hence, presumably, it does not pay to attempt it.

I refer particularly to those large excavations in the chalk, because they would be prejudicially affected if the "saturation levels" were brought up to the high-tide levels. In some districts, the flow through the chalk is very copious, as at the Northfleet Coal and Ballast Pits, where it has been tested by very extensive pumping. In other districts it is comparatively slow, no doubt largely depending upon the presence or absence of fissures, whose existence can never be foretold. Hence it is impossible to argue from any one instance what might happen in different parts of the chalk.

As to "Impermeable," "Permeable," and "Mixed" Beds over Chalk.

We need only concern ourselves with the nature of the soils in the Thames Valley in so far as it affects the question of "permeability." As to this subject, the best evidence we have of the permeabilities of different soils is in connection with rainfall and its percolation, a subject to which I have given considerable attention in my official

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capacity as Secretary to the Underground Water Preservation Association. We will consider this matter first in relation to chalk.

A set of maps were prepared by Mr. William Whitaker, F.R.S., for the Metropolitan Board of Works, showing the areas over which rain water could percolate to the chalk. They are coloured in accordance with "permeable," "impermeable," and "mixed" beds in relation to the chalk.

Water could rise up out of the chalk where bare, or covered by "permeable" beds, but less readily where covered by "mixed" beds, and not at all where covered by "impermeable" beds. I have copies of these maps by me for reference, by the aid of which, in conjunction with the map prepared by Mr. Hennell (*see* page 100) showing the land below high-water mark and contributing drainage areas, I have constructed Table (1).

TABLE I.

AREAS OF PERMEABLE, IMPERMEABLE AND MIXED BEDS IN RELATION TO PERCOLATION TO AND FROM CHALK.

(Areas in Square Miles.)

Areas as indicated in Mr. Hennell's Map.	Area below H.W.M.	Contributing Drainage.	AREA BELOW H.W.M.			AREA ABOVE H.W.M.		
SOUTH SIDE OF THAMES.			Permeable.	Mixed.	Impermeable.	Permeable.	Mixed.	Impermeable.
1. Swanscombe Marshes	·5	—	—	·5	—	—	—	—
2. Dartford and Stone Marshes ..	1·8	10·0	—	1·8	—	8	1·0	1·0
3. Between Cray and Darenth ..	·3	·5	·1	·2	—	·5	—	—
4. Crayford Marshes	·6	2·0	—	·6	—	1	·1	—
5. Erith Marshes, &c...	2·6	6	·1	2·5	—	1·3	3·9	·8
6. Plumstead Marshes..	2·3	—	—	2·3	—	—	—	—
7. Greenwich Marshes..	1·1	2·5	—	1·1	—	·8	1·7	—
SOUTH SIDE TOTALS	9·2	21·0	·2	9·1	—	11·6	7·6	1·8
NORTH SIDE OF THAMES.								
8. Little Thurrock and Grays Marshes	·9	—	—	·9	—	—	—	—
9. West Thurock	1·4	5·0	—	1·4	—	7·0	2·5	40·5
10. Rainham, Wennington and Avelly Marshes	3·4	—	—	3·4	—	—	—	—
11. Barking Level, Ripple Level and Dagenham and Hornchurch ..	4·3	3·8	—	—	4·3	—	—	3·8
12. W. Ham, E. Ham, Plaistow Marsh, N. Woolwich Marsh	5·5	·6	—	1·7	3·8	—	·6	5·4
NORTH SIDE TOTALS	24·7	·94	—	7·4	8·1	7·0	3·1	83·9

SUMMARISED FROM TABLE (1).

		Square Miles.
SOUTH SIDE—		
Below H.W.M.	.. Permeable	·2 Uncertain.
,, ,, ...	.. Mixed	9·2
,, ,, ...	.. Impermeable	*Nil.*
SOUTH SIDE—		
Above H.W.M. ..	.. Permeable	11·6
,, ,, ..	.. Mixed	7·6
,, ,, ..	.. Impermeable	1·8
NORTH SIDE—		
Below H.W.M.	.. Permeable	Uncertain.
,, ,, ...	.. Mixed	7·4
,, ,, ...	.. Impermeable	8·1
NORTH SIDE—		
Above H.W.M.	.. Permeable	7·0
,, ,, ...	.. Mixed	3·1
,, ,, ...	.. Impermeable	83·9

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As to the Distribution of Beds over Chalk.

The maps above referred to show that practically the whole of the land below high-water mark is covered by "mixed" beds (to which detailed reference will be made later) extending right away from the surface down to the chalk. Judging from these maps, if the "saturation level" rose in the chalk by infiltration from the river, it would not be impeded from overflowing the land and finding a common level with the river water.

These "mixed" beds are less permeable than the bare chalk and gravel, but, nevertheless, generally speaking, are sufficiently permeable to allow the rain water to percolate through. It may be taken generally that the whole of the low-lying marsh land may be regarded as consisting of beds of this nature, although locally and in parts the beds may vary in permeability right away from that of bare chalk to stiff clay. The limits of these "mixed" beds are not sufficiently well defined on my one-inch chalk area maps to enable me to say how far the bare chalk land extends below high-water mark. I shall, therefore, make local references in this report to the low-lying bare chalk.

As to Percolation into Chalk Wells.

We have ample evidence of the passage of river water into the chalk from the analysis of the water in the wells and their rise and fall. The river water appears often to come in just in proportion as the difference in levels increases. This has been tested in a well drawn down by continuous pumping.

The salt found in the water of these wells cannot be (beyond a mere trace, which is allowed for) from any source other than the river, and where the rise and fall of a well closely follows that of the tide, we have corroborative evidence of infiltration.

It appears highly probable that if the water of the river were maintained permanently at high-water mark, the water level in the chalk, as at Erith, Purfleet, Grays, Northfleet, &c., would soon permanently rise (unless kept down by pumping). Presumably much of this water would reach the marsh land by way of the chalk formation. How far it would escape in this way it would be difficult to foretell.

As to the Travel of Water through the Chalk.

Water is capable of travelling in large quantities through chalk to distant points. The water pumped from the chalk of the London basin is known to exceed 100 million gallons per diem, and may be far in excess of this quantity, and much of it has travelled long distances from the time it first entered the chalk. Thus, the water pumped from the deep borings in the centre of London is the result of rainfall on the Chiltern Hills and North Downs, where it enters the chalk and travels through it to the London wells. Water is, therefore, conveyed great distances and in large quantities through the chalk and at a comparatively small gradient.

Water travels through the chalk by means of fissures. Every million gallons of water extracted from the chalk, according to Dr. Thresh, carries with it in solution on an average 1¼ tons of chalk, through which it has percolated, and thus leaves a space equal to an additional volume of 110 gallons of water. By this means, unless subsidence of the land takes place, the liability to further infiltration may be increased.

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There is a case cited by Dr. Thresh, of a well a mile-and-a-half from the shore being affected by the ingress of sea water. I examined the Margate water a few years ago, and found one part of sea water in 16 of well water, before the new pumping station was built further inland. The distance here traversed by the sea water through the chalk was about half-a-mile. The sea water appeared to come in more as the differences of levels increased.

As to the Chalk Springs in the Bed of the Thames.

That water passes, or did pass freely, into the bed of the Thames from the chalk was a matter of common knowledge to many who lived in the neighbourhood of Erith. On account of the greatly increased pumping by the various industrial concerns and water companies, there is now in parts of the Thames Valley no longer any surplus water in years of average rainfall. This surplus water 20 or 30 years ago, could be seen welling up like so many springs at low tide. Had this quantity been inconsiderable, I do not think that it would have been so noticeable. Whether these springs still rise in places I am unable to judge, but presumably they do in very wet years. In average years the flow at times is in the opposite direction, judging from the amount of salt in some of the large wells.

Particular note was taken of these chalk springs in evidence before the Duke of Richmond's Commission, 1869, and subsequent Commissions. The following is an extract from the Report of the first named. Paragraph 76, page 33 :—

> Mr. P. W. Barlow, civil engineer, believes that the ultimate solution of the difficulty of supplying London will be found in the chalk. He has found several powerful springs issuing from the chalk on the south side of the Thames ; in one small district near Gravesend they amount to 10 million gallons per day. He believes that by driving a tunnel parallel with the river, 20 miles long, from Lewisham to Gravesend, or a little beyond, 60 million gallons per day might be obtained.

If water can come up as springs in the bed of the river in such enormous quantities, surely, if the pressure is exerted in the opposite direction, the water will flow backwards through the bed of the river into the chalk. It is not as though there was a great pressure at the back of the springs, because there is no evidence of the water flowing outwards except at low tide. It must be presumed, therefore, that at high tide the water would flow in the opposite direction, and that if the water were permanently maintained at high tide, it would always flow in this direction, until the "saturation levels" in the chalk came up to that of the river level.

The following is an extract from the Balfour Commission, 1893, Section 97 :—

> At Erith large bodies of water are actually seen issuing from the bed of the river. In like manner the Lee below Hertford increases as it flows along by additions poured into it from the chalk over which it passes.

As to Water Reversed in Flow through Springs.

We have records of two well-known cases of springs in the bed of rivers being reversed in their flow when the level of the river was above that of the "saturation level" of the source from which the springs derived their flow ; as, in my opinion,

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would be the case so far as the chalk springs in the bed of the river are concerned, if the Thames were permanently held up to high-water level. That the water of streams or rivers can literally leak away and disappear from the surface is, of course, well known.

In speaking of the water pumped from the Thanet Sands by the Southwark and Vauxhall Water Company from a well at Streatham, and to account for the presence of so much water, in the Report of the Balfour Commission, paragraph 102, it is stated :—

> It has been suggested that the water thus raised from the Thanet sand is really chalk water which finds its way into the sand from the Wandle where that stream runs across its outcrop. Whatever be its origin, the quantity of water yielded by the Thanet sand in this district is considerable. A large number of wells in the lower part of the Wandle Valley still overflow.

As to Leakage through Chalk without Silting.

That the Thames itself, near its source, affords proof of possible infiltration through chalk without silting up after passing over clay, can be judged from the following extract from a communication by Lord Avebury :—

> An interesting case is afforded by the head waters of the Thames flowing from the Seven Wells. Mr. Simpson has measured the flow for the first 15 miles, with the following curious result. The discharge from the spring head was in one minute 11 cubic feet. For the first 5½ miles, which are over Lias clay, the flow gradually increased to 320 cubic feet Then the river reaches the Oolites, into which the water begins to sink, so that the flow at—

6½	miles	became	..	..	..	..	..	290	cubic feet.
7	,,	,,	..	..	..	..	..	235	,,
7⅝	,,	,,	..	..	..	..	..	179	,,
8⅛	,,	,,	..	..	..	..	..	113	,,
8⅞	,,	,,	..	..	..	..	..	45	,,
9¾	,,	,,	..	..	..	..	..	33	,,
12½	,,	,,	..	..	..	..	..	30	,,
14½	,,	,,	..	..	..	..	..	10	,,

As to the Sub-soils of the Thames Valley.

The ordinary geological map does not indicate the nature of the sub-soils, nor do the chalk area maps (already described) do so. A map constructed to show the sub-soils in the Thames Valley (*see* p. 83) affords valuable aid to us in regard to the liability to infiltration from the river other than that of the chalk. From a map so constructed, it will be noticed that the alluvium of the river is fringed on the North to some distance by valley gravel and sand, which are freely percolated. Right through London this is the case, until we reach the River Lea. Soil of this nature extends from Blackwall to Stoke Newington. On the East of the Lea and North of the Thames this gravel and sand extends unbroken from Plaistow Level to Tottenham, including Wanstead and Leyton. After passing the alluvium of the Roding, it extends from Barking to Purfleet, where it meets with the chalk. It includes, on the North, Barking Side, Romford, Hornchurch, North and South Ockenden, and appears again North of Tilbury in contact with chalk, Blackheath and Woolwich beds, Thanet Sands, etc., all of which are permeable. This freely permeable soil is frequently 50 feet deep. A great portion of this district is below high-tide level. The same condition prevails

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here and there on the South side. As an instance of "permeable" soils, I give below (Table 2) six well sections in Bermondsey :—

TABLE 2.

BERMONDSEY WELL SECTIONS.

WELL SECTIONS. No.	1.	2.	3.	4.	5.	6.	MEAN.
*O.D. Level of ground	7	9	11	12	10	9	9½ ft.
Thickness of freely permeable soils below surface	23	21	29	45	32	19	28 ft.

* From Whitaker's "Geology of London," Vol. 2.

If, as I believe possible, river water can freely percolate at Bermondsey, as I have proved it does at London Bridge, with the river permanently at high-water mark, I should anticipate that cellars, driving pits and foundations of buildings might very readily be flooded by ingress of river water.

I give in Table 3 a list of some places in the Valley of the Thames with approximate O.D. Level and abbreviations, showing the nature of the soils. By the aid of this table some idea may be formed of the liability to infiltration. It must be borne in mind, however, that except within reasonable distance of the river, in those districts where pumping is carried on to a large extent, chiefly for industrial purposes, the "saturation levels" will be artificially kept down. Those districts where unshielded wells are sunk through the gravel, sand, &c., the gravel water will reach the wells; but with deep wells, shielded and piercing the London clay, and pumped from the chalk, the rising water in the gravel will not be kept down by the pumping operations.

TABLE 3.

LIST SHOWING DISTRICTS IN THAMES VALLEY, WITH APPROXIMATE O.D. LEVEL OF PRINCIPAL HEIGHTS AND NATURE OF SUB-SOIL.

Note that the O.D. Level figure in parts of each district is sometimes much lower than the figure given. Thus, Belvedere is given at 75 feet, whereas a very large proportion of the population lives below high-water mark, the village being extended into the marshes; the same with Plumstead, Abbey Wood, Erith, Crayford and Dartford, and, of course, as far as factories are concerned, in many places on the North side of the river as well as the South.

The letters which follow the names of places refer to the geological formation there, represented as follows :—(Adopted by Horace B. Woodward, F.R.S.)

A.	Alluvium (Marshland).
Bcl.	Boulder Clay.
Bg.	Bagshot Beds (chiefly Sand).
Bl.	Blackheath Beds (Gravel).
C.	Chalk.
Clf.	Clay with Flints and Loam.
G.	Gravel and Sand of higher grounds.
Glt.	Gault (Clay).
H.	Hastings Beds.
L.	London Clay.
Lg.	Lower Greensand.
Lm.	Loam (Brickearth).
T.	Thanet Sand.
Ug.	Upper Greensand.
Vg.	Valley Gravel.
W.	Woolwich and Reading Beds (mixed Gravel, Sand and Clay).
Wd.	Weald Clay.

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Districts.	Approximate O.D. Level.	Sub-soil, &c.
Abbey Wood, Plumstead	100	Bl. T. W.
Barking	20	Vg.
Barking Side	97	Lm. Vg.
Battersea	15	Lm. Vg.
Belvedere, Erith	75	A. Bl. T. W.
Bermondsey	10	A.
Blackfriars	25	Vg. L.
Blackwall	20	A.
Bow	36	Vg.
Brentford	30	Lm. Vg.
Brixton	20–80	L. Vg.
Bromley, Bow	20	Vg.
Camberwell	15–30	Vg.
Charing Cross	25	Vg.
Chiswick	24	Lm. Vg.
Crayford	100	C. Lm. T. Vg.
Cubitt Town, Isle of Dogs	—	A.
Dagenham	20	Vg.
Dartford	50	C. Vg.
Deptford	20	A. Vg.
Erith	25–50	C. T. Vg.
Fulham	20	Vg.
Gallions Point	—	A.
Gravesend	20–100	C. T.
Grays	30	C. Lm. Vg.
Greenhithe	20	C.
Greenwich	14–150	Bl. T. Vg. W.
Ham	25	Vg.
East Ham	15	Vg.
West Ham	10–20	Vg.
Isle of Dogs	10–20	A.
Lambeth	14–30	A. Vg.
Millbank	14	A.
Millwall, Isle of Dogs	10	A.
Newington Butts	11	Vg.
Nine Elms	15	A. Vg.
Northfleet	—	C. T.
Plumstead	50–100	T.
Poplar	22	Vg.
Purfleet	21	C.
Rainham	16	Vg.
Rainham Ferry	—	A.
Rotherhithe	10	A.
Silvertown	8	A.
West Thurrock	20	A. Vg.
East Tilbury	—	A. C. Lm. Vg.
West Tilbury	—	A. T. Vg.
Woolwich	20–150	Bl. C. T. W.

Table 4 gives us some idea of the localities (or, at least, such as the Geological Survey Records enable us to select) where, if the "saturation levels" were put under pressure, the water would not be impeded from rising to the surface. Of course, we need not concern ourselves with districts on high ground.

Table 5 gives some of those districts where the water would not rise. It must be borne in mind that, in both cases, we can only judge of the well sections; other sections or trial holes might show opposite results. Thus, although we find four sections of "Impermeable" soils in Belvedere and Erith Marshes, it does not follow that the whole

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of these marshes are "impermeable." It is very easy to be misled in this way. In making an analysis of the sections given in Tables 6 to 10, I find that the alluvium and river drifts vary enormously in permeability, as shown by comparing sections close to one another.

TABLE 4.

TABLE GIVING LOCALITIES SHOWING THE DEPTH IN FEET OF SOIL THROUGH WHICH WATER WOULD RISE TO THE SURFACE. ABSTRACTED FROM MEMOIRS OF GEOLOGICAL SURVEY.

The O.D. Level or the T.H.W. Level is given where possible.

(The Asterisk shows where "Permeable" Soil reaches the Chalk.)

Localities.	Depths of Permeable Soil from Surface.		
	At Sec. 1.	At Sec. 2.	At Sec. 3.
Barking	51 feet	40 feet	—
Grays	*24 ,,	—	—
Southend	35 ,,	—	—
Dartford Creek	*46 ,,	—	—
Deptford	*50 ,,	—	—
Gravesend	*23 ,,	*66 feet	—
Woolwich	*54 ,,	—	—
Bromley-by-Bow	19 ,,	16 ,,	18 feet
Isle of Dogs	59 ,,	56 ,,	—
Chiswick	40 ,,	34 ,,	37 ,,
	36 ,,	19 ,,	—
	O.D. 24	O.D. 23	O.D. 20
Isle of Dogs	56 feet	—	—
Isleworth	20 ,,	24 feet	—
Millbank	27½ ,,	26 ,,	—
	O.D. 5½	—	—
Pimlico	32 feet	26 feet	—
	O.D. 0	O.D. 1	—
Minories	24 feet	—	—
Tottenham (8 Sections)	15–20 ,,	—	—
Tower Hill	35 ,,	—	—
	O.D. 30	—	—
Trafalgar Square	23 feet	—	—
	O.D. 29	—	—
Barnes	25 feet	35 feet	32 feet
	19 ,,	O.D. 15	O.D. 15
	5½ below T.H.W.M.	—	—
Lambeth	28 feet	26 feet	20 feet
	O.D. 12	O.D. 15	O.D. 13
	25 feet	40 feet	—
	O.D. 12	—	—
Southwark	34 feet	27 ,,	—
	O.D. 15	—	—
Old Kent Road	23 feet	*30 ,,	*39 feet
	O.D. 12½	O.D. 10	—
New Cross	31 feet	—	—
Greenwich	159 ,,	44 feet	38 feet
	—	7 above T.H.W.M.	—

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TABLE 5.

LIST OF DISTRICTS WITH IMPERMEABLE SOILS THROUGH WHICH WATER WOULD NOT RISE TO THE SURFACE.

	No. of Well Sections.
East Ham	1
Beckton	1
Plaistow	3
Purfleet	1
Tilbury	1
Walthamstow	2
Belvedere Marshes and Erith	4
Millbank	1
Pimlico	1
Battersea	1
Vauxhall	1
Wandsworth	1
East Ham	4

PERMEABILITY OF ALLUVIUM, RIVER AND VALLEY DRIFT.

In order to form some idea of the ease with which water will pass through the above-mentioned deposits, I took particulars of 154 trial borings. If the surface consists uniformly of clay for a few feet downwards with the river at high-water mark, water if it passes in below the walls from the river cannot rise to the surface. Its likelihood of rising to the surface will, therefore, depend on the permeability of the surface deposit. I have classified the surface deposits under five headings in ascending order of permeability.

No. 1. Clay.
„ 2. Loamy clay or loam and clay.
„ 3. Loam.
„ 4. Loamy sand or loamy gravel.
„ 5. No loam or clay.

No. 1 is completely impermeable.

No. 2 probably impermeable in many cases; in others very slightly permeable.

No. 3 slightly permeable, but variable.

No. 4 more permeable.

No. 5 equal in permeability to "permeable" beds and perhaps to bare chalk.

I have rejected any doubtful cases, such as those containing peat and other deposits, the permeability of which is too uncertain to classify.

The results of different localities are summarised in Tables Nos. 6 to 9. These are all put together and given in Table 10. In each table the average O.D. levels are calculated, and the highest and lowest O.D. levels are given.

It must be remembered that any land below about 12½ feet above O.D. would be inundated, if the water levels of the marsh were free to rise to that of the high-water mark of the river. The final figures of the 154 sections show (5) 26·5 per cent. "permeable" and (4) 25·1 per cent. of loamy sand, &c., which latter might be taken to have

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half the permeability of No. 5. Leaving out of consideration for the moment Nos. 2 and 3, this gives an all-round average for the whole of the alluvium, valley and river drift of 40 per cent., as compared with "permeable" beds.

We know that the water can enter underneath the river wall into the ballast, gravel, sand, &c., underlying the marshes. As the area of the marsh land is so great in comparison with that of the sectional area of the permeable deposits, through which the water makes its ingress, it stands to reason that if the marsh land is overlaid in patches equal to 60 per cent. of its area with impermeable beds, such beds would not offer any material resistance to the water rising to the surface.

I am afraid, therefore, that we must regard the surface of the marsh land, taking it as a whole, as offering very little resistance to the ingress of water. The same remarks apply to the valley and river drifts.

TABLE 6.

SECTIONS OF TRIAL BORINGS FROM THE NORTH SIDE OF THAMES, FROM WALHAM GREEN TO BLACKFRIARS BRIDGE, SHOWING NATURE OF SURFACE OF ALLUVIUM AND VALLEY DRIFT, ARRANGED IN ASCENDING ORDER OF PERMEABILITY.

	No. of Trial Sections.		Percentage of Total.
1. Clay	6	=	10·7
2. Loamy clay or loam and clay	7	=	12·5
3. Loam	15	=	26·8
4. Loamy sand or loamy gravel	10	=	17·9
5. No loam or clay	18	=	32·1
	56		100·0

Mean level of surface sections, 32 above O.D.

TABLE 7.

SOUTH SIDE THROUGH WANDSWORTH, BATTERSEA, NINE ELMS, KENNINGTON, CAMBERWELL, OLD KENT ROAD, NEW CROSS, BERMONDSEY, DEPTFORD, GREENWICH, PLUMPSTEAD, CROSSNESS.

	No. of Trial Sections.		Percentage of Total.
1. Clay	13	=	24·6
2. Loamy clay or loam and clay	7	=	13·2
3. Loam	6	=	11·1
4. Loamy sand or loamy gravel	10	=	18·9
5. No loam or clay	17	=	32·2
	53	=	100·0

Of the above Sections, taking them in order where O.D. Levels are mentioned:—

	Average.	Highest.	Lowest.
No. 1 to 4 (4).. ..	21·1 feet above O.D.	30 feet ..	13 feet
„ 5 to 14 (10).. ..	11·4 „ „	16 „ ..	2 „
„ 5 to 24 (10).. ..	10·2 „ „	11 „ ..	6 „
„ 25 to 34 (10).. ..	11·6 „ „	22 „ ..	6 „
„ 35 to 38 (4).. ..	9·8 „ „	16 „ ..	4½ „
Mean of 38 Sections..	12·0 „ „		

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TABLE 8.

FROM WESTMINSTER BRIDGE TO LAMBETH ALONG THE EMBANKMENT.—

	No. of Trial Borings.	Percentage of Total.
1. Clay	—	—
2. Loamy clay or loam and clay	1	= 9·1
3. Loam	1	= 9·1
4. Loamy sand or loamy gravel	7	= 63·6
5. No loam or clay	2	= 18·2

Mean O.D. Level of above being = 7·97 above O.D.
Highest " " = 15·85 "
Lowest " " = 1·02 "

TABLE 9.

FROM BARKING, EAST HAM, PLAISTOW, BOW, LIMEHOUSE, ISLE OF DOGS, BLACKWALL.

	No. of Trial Borings.	Percentage of Total.
1. Clay	15	= 44·1
2. Loamy clay or loam and clay	5	= 14·7
3. Loam	6	= 17·7
4. Loamy sand or loamy gravel..	—	—
5. No loam or clay	8	= 23·5
	34	= 100·0

Of the above Sections, taking them in the order in which O.D. Levels are given:—

	Average.	Highest.	Lowest.
No. 1 to 4 (4)	17·5 O.D.	27 O.D.	2 O.D.
" 5 to 14 (10)	8·8 O.D.	18 O.D.	2 O.D.
" 15 to 24 (10)	13·3 O.D.	24 O.D.	3·1 O.D.
" 25 to 29 (5)	10·8 O.D.	19 O.D.	6·6 O.D.

TABLE 10.

SUMMARY OF FOREGOING.

	Table 6.	Table 7.	Table 8.	Table 9.	Average of Tables 6–9
1. Clay	10·7	24·6	—	44·1	19·8
2. Loamy clay or loam and clay	12·5	13·2	9·1	14·7	12·4
3. Loam	26·8	11·1	9·1	17·7	16·2
4. Loamy sand or loamy gravel	17·9	18·9	63·6	—	25·1
5. No loam or clay	32·1	32·2	18·2	23·5	26·5
	100·0%	100·0%	100·0%	100·0%	100·0%

Tables Nos. 6—10 contain results of 154 Trial Holes.

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I have, with Dr. H. P. Stevens, made numerous determinations of the amount of chlorides in well and river water taken from different parts of the Darenth and Cray watersheds, and have examined the figures for the Upper Thames and for the different wells of the Kent Water Works Company; and, in consequence, I put the figure for the natural chlorides at 2 grains per gallon (as chlorine). When the figure exceeds this to any extent for water pumped in the neighbourhood of the river, the excess quantity may be put down to the ingress of river water; but if it is only slightly exceeded, no notice should be taken of it.

I had occasion to examine the condition of three wells in Dartford in 1904, a copy of my Report on same I am permitted to refer to. This Report shows the liability to periodical flooding, and, in consequence, Messrs. J. & E. Hall, Ltd., raised the level of their boilers so as to keep them out of the dangerous limit. Such conditions as those pointed out in my Report would be aggravated by keeping the river level at high-water mark, unless the pumping capacity is locally sufficiently elastic to take away all surplus water in very wet weather.

In the same year, I noted the behaviour of a well in Southwark Street. The chemical analysis was undertaken by Dr. H. P. Stevens. This presents a very clear case of "infiltration" of river water to a considerable distance inland. The water showed a rise and fall of six feet with the tide, and rather more salt at high than at low tide. I calculated that from 10 to 14 per cent. of this well water is derived by infiltration from the Thames. I mention this case as showing that the Metropolitan areas are as liable to infiltration as the marshes down the river.

In 1903 the Underground Water Preservation Association was studying the composition of wells in the neighbourhood of the Thames, with a view of ascertaining how far this water might be available for drinking purposes; and the following extract of the Report for that year, giving the results of an investigation made by Dr. H. P. Stevens and myself, is of service in throwing light on the subject of infiltration from the river at different points:—

> The chemical composition of water is also a matter which is being fully considered by your Association, more especially in regard to the infiltration of Thames and brackish water along the low-lying lands of the Thames Valley. For the purpose of this investigation numerous samples have been taken and analysed. Out of ten typical samples (Table C) taken from districts from New Cross down to Northfleet, four of them show between 5 and 7 per cent. of Thames water, one 15 per cent., two 25 per cent., and one consisting almost wholly of Thames water. Most of the large works in this locality have abandoned their wells for drinking purposes. On the marshes, between Plumstead and Erith, water pumped from the ballast 250 feet from the Thames is almost wholly derived from the Thames. Wells sunk to a depth of 300 feet, with a shield for the first 200 feet, in this locality yield very bad water; and at a depth of 180 feet, with a shield reaching down 90 feet, the water pumped from the chalk contains 25 per cent. of river water. The brackishness of the water is found to be increased as the levels are depressed by pumping. The effects of infiltration may extend half-a-mile or more inland, as the levels are lowered, rendering the water, even at this distance, entirely unfit for drinking purposes (as in the case of the Margate Water supply).

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TABLE C.

A few instances of infiltration of Thames water into large wells used by industrial concerns, arrived at by comparing the composition of the Well water with that of the nearest Thames water.

SALTNESS IN GRAINS OF CHLORINE PER GALLON.

Location of Well.	Well water. Grains per gallon.	Mean for River water. Grains per gallon.	Proportion of Thames water in Well water pumped.
New Cross ..	90	50 to 500	Say 25 per cent.
Charlton	29	100 to 700	,, 7 ,,
Woolwich	37	150 to 800	,, 7 ,,
Erith Marshes (1) ..	250 to 1000	250 to 1000	Nearly all river water.
,, ,, (2) ..	175	250 to 1000	Say 25 per cent.
,, ,, (3) ..	40	250 to 1000	,, 6 ,,
Northfleet (1) ..	175 to 250	700 to 1400	,, 15 ,,
,, (2) ..	34	700 to 1400	,, 5 ,,

Since the publication of the above quoted Report, we have met with the following cases :—

Location of Well.	Well water. Grains per gallon.	Mean for River water. Grains per gallon.	Proportion of Thames water in Well water pumped.
Dartford	—	—	About 5 per cent.
Purfleet	102	300 to 1200	,, 12 ,,
Northfleet	175	700 to 1411	,, 16 ,,
Charlton	32	200 to 500	,, 8 ,,
New Cross ..	54	100 to 400	,, 10 ,,

In my evidence prepared on behalf of the Court of Arbitration, the Metropolitan Water Board and the Kent Water Works Company, in taking stock of the amount of water pumped by various concerns within the area of the Kent Water Works Company, I was obliged to make deductions for the amount of infiltration from the River Thames.

In the aggregate, I found it necessary to deduct about 3 million gallons per diem for the water percolating from the river to the wells existing on the low lands within the area of the Kent Water Works Company—*i.e.*, between Deptford and Swanscombe.

If, therefore, infiltration took place in a similar ratio for all the wells in the neighbourhood of the Thames, the amount of river water passing into the wells might easily amount to 10 million gallons per diem, or a great deal more.

Mr. Baldwin Latham, in a paper entitled " Indication of the Movement of Subterranean Water in the Chalk Formation " (*see* Report, No. 1,877), deals extensively with this subject. He states :—

The flow of water laterally is from the hills to the valleys, and longitudinally down the valley-lines ; therefore, as a general rule, the flow of subterranean water conforms to the surface-falls of the country. There are, however, exceptions to this rule, as the author has found in several instances.

The flow of water under the marshes of the Thames, in so far as it has been taken note of, conforms, so I believe, to Mr. Baldwin Latham's rules, qualified by the remarks made in his paper.

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It is important to realise that this underground water is in motion and contiguous with that of the river, only that it is out of sight, and is, of course, much more sluggish in its motion. Not only does the water appear to travel down the river, but the underground water is also tidal in many parts.

In keeping down the "saturation levels" with the tide permanently at high-water mark, the removal of water higher up, as at Plumstead, would, presumably, intercept a great deal flowing down the valley, and possibly lessen the quantity to be removed, say at Belvedere or Erith.

Where the river takes a sudden bend, as at Northfleet, the underground water appears to take a short cut across the promontory from one reach to the other, without following the river in all its windings.

As to the possible Effect of Permanent High-Water on Marshes.

If the river were permanently held up to high-water level, marshes, such as those at Belvedere and Erith would in parts respond. Water would in my opinion quickly make its appearance in the pits of Messrs. Callenders' works. This is evident from the fact that it does so now at extraordinary high tide, and disappears on the fall of the tide. The ballast here at a depth of 30 to 40 feet would be charged with water under a pressure equal to that of the high-tide level. Where it could find an outlet by rising to the surface, it would do so; but many parts of the marshes are too impervious to permit it to do so. How fast it would rise and what amount of pumping would be necessary to prevent it from rising, it is impossible to say. It is difficult to say, also, whether pumping along the bank would have the necessary effect in keeping those and similar marshes sufficiently dry. The river water would charge the ballast, and, presumably, create a pressure at all points; but this layer of ballast is protected from the surface by 10 to 20 feet of clay. The ditches, which only reach down a few feet, would not touch the ballast water. So long as the ballast is sealed at all points the marshes might remain dry; but where clay is pierced or absent the water will rise to the surface and overflow into the ditches, from whence it could be pumped back into the river. But to permit the "saturation levels" to rise more than a foot or two would be disastrous to many works.

General Remarks.

Water enters, or is liable to enter, on either side of the river under the banks. In many places water cannot rise to the surface of the marsh on account of the impervious nature of the alluvium. Where underlaid by ballast deposits communicating with the river, if such impervious surface deposits are cut or artificially removed, water will rise from the ballast and reach that of the river level. Trial borings show sudden local changes from pervious to impervious coatings. The impervious coatings are not sufficiently universal to generally shut out the rising water. There will be a natural tendency for the river water to find its way into the chalk, gravel, ballast, and all "permeable" beds, until the water finds a common level, unless pumped, or drained to stations where it can be pumped. A large part of the Thames flows through

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"permeable" beds which communicate inland to low-lying marshes. That water at present can percolate freely from the river into these beds is evidenced by tidal wells, salt in water, &c.

The chalk springs in the lower Thames are strong indications of the direct communication of river water with water in the chalk beds. The chalk formation in the Thames Valley is largely covered by beds which permit a more or less free passage of water upwards to the surface.

The river, where properly covered by river mud,' may become water-tight, even when the bed on which it deposits is gravelly or contains ballast.

As to Bare Places in the River Bed.

There are many parts of the bed of the river where gravel is bare. In such places the river water would penetrate freely. The same may be said of the ballast.

Even where the surface of the land is many feet above high-water mark the water percolating into the gravel may do damage to buildings, foundations, &c., which are deep enough to be affected. Where the wells are not shielded the water may pass into them, and the pumping from these wells should materially assist keeping the wells down.

I understand that Mr. Dibdin holds the view that the Thames water under the altered conditions might be filtered for drinking purposes. Presumably this could refer only to the Thames above Crossness and Barking, above the outfall works, or zone of contamination. Such water passing from gravel into wells may not cause pollution, in fact, the gravel is a most effective filter; but there is a risk of its doing so here and there, where the water from the Thames passes through thickly populated districts, where the sub-soil is already contaminated. Wells used for manufacturing purposes may be greatly benefited by the ingress of water, as well as themselves assisting in keeping down the "saturation levels" to a safe limit by their own pumping.

There are districts, such as Bermondsey, where the surface is so close to high-water level as to render a rise of water in the gravel harmful to houses and factories with basements, cellars, pits, &c., and the drainage of which would have to be made to carry off any water above a certain level to be determined upon.

As to the Deposit of River Mud.

It is difficult to say whether water continually filtering from the river into the marsh land would cause the mud to deposit on the surface of the bed and so pug the bed of the river. That such a passage of water continually passing does not necessarily cause the mud to deposit and pug the river, is evident from the fact that large quantities of river water have for many years been pumped through 350 feet of ballast, and after these years of pumping the flow of this water does not appear to be impeded.

The river is likely to flood the low-lying land by way of the chalk. Although the water in places readily enters the chalk from the bed of the river, it may in places experience considerable difficulty in getting out on the land side. I regard the ballast

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as being very permeable to water, and to shut out the water from passing into the ballast under the marshes the wall would have to be carried down in places 40 or 50 feet below the surface.

The river is laid bare of mud in many places by the dredging and by the scour of the tide. These bare patches are probably augmented by water which at present percolates at high tide, and on passing back into the river at low tide blows the mud away from the surface. But with a dockised river the scour would cease and further dredging might be prohibited.

As to the River Mud Settling.

With the constant high water and flow of less than one mile per hour, this mud might settle on the gravel, ballast, &c., and in time reduce the liability to infiltration. I do not think it would settle so rapidly on the chalk where large fissures abound. It is not easy to form a definite opinion on this point. I cannot say whether the river mud is in itself water-tight. The mud, I presume, to be variable in character and composition, depending largely upon the state of flow of the upper Thames. Furthermore, the mud would vary considerably in composition at different parts of the river.

As to the Redistribution of Mud.

As to the distribution of mud under these altered circumstances, presumably there would still be some disposition to scouring, as heretofore. I should anticipate, however, that the mud would be drawn on to the surface of the ballast by infiltration (the ballast acting as an effective filter). This retention of mud would have an increasing tendency to diminish infiltration as time went on. If, however, the ballast shifted and was distributed at any time, it would be again laid bare.

I should anticipate that the natural pugging of the gravel with river mud would be less likely to take place than with the ballast. In parts of the Thames one sees now at low tide clean washed shingle which must be highly pervious. This is continuous with the land gravel running back through the river. Here the scour is now so powerful as to wash out all fine particles, leaving nothing but larger stones, as on the sea shore. Whether, under the altered conditions, this scour would be sufficiently reduced as to permit of the deposit of fine mud at these points, it is not possible for me to predict. I consider, however, that this point might be proved by experiments.

As to the Natural Pugging.

That gravel does become pugged by the deposit on its surface of mud or silt—sufficient, at any rate, to offer considerable resistance to the ingress of water—is evident from the following evidence taken from the Report of Lord Balfour's Commission :—

> We have ascertained that in the reach of the river, extending in front of these works, and in fact lower down, opposite those of the Grand Junction and Southwark Companies, the dredging of gravel is almost continuously going on. Under normal conditions the gravel is coated with a few inches of fine argillaceous silt, which is not freely pervious ; but where the dredging operations remove this, there is, of course, free passage for water either from the land to the river, or from the river to the land in whichever way for the time being the water has a dominant head.

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It is, we think, quite clear that if an artificial depression is produced in the level of the water in the ground by pumping anywhere in close proximity to the river, water must inevitably be drawn out of the river, and it would be quite impossible to differentiate between that and the water flowing from inland which had never got into the river.

It would appear from the above quotation that a "few inches" (say, 4 inches) of fine silt on gravel beds would offer resistance equal to, say, 2 feet of water. We should require, possibly, five times this thickness of deposit to entirely overcome the resistance due to the permanent high-water level. But the argillaceous silt referred to is undoubtedly of a better pugging nature than the mixed mud of the lower Thames. Nevertheless, it seems quite conceivable that a sufficiently thick layer might be produced in a reasonable period to greatly diminish the percolation into the gravel, and, in time, perhaps to prevent it altogether.

It must not be forgotten that permeability is largely, though not wholly, a matter of pressure, and we need not, therefore, concern ourselves with percolation that requires a greater pressure than 10 and 12 feet of water.

As to the Difficulties of Pugging Chalk.

The bare chalk not being a filtering medium, like the ballast or gravel, I doubt very much whether mud would adhere to it. Where mud settles on the chalk, as at Erith, I have noticed that it is easily laid bare, as, for instance, by the sluices. Also mud easily slides down chalk unless the bed is fairly horizontal. Therefore layers of mud on chalk might slide off, or be otherwise dislodged at any time.

There are on record several cases of rivers whose waters are periodically drawn down into the chalk in "swallow holes," which do not appear to be pugged or filled up as time goes on. This would rather argue against the chalk fissures in the Thames getting filled up and pugged. There is, however, geological evidence to show that the chalk underlying Thanet beds, &c., gets coated with a clayey deposit which offers resistance to the passage of water. I hardly expect that such a deposit could take place in the bed of a river in running water; but this deposit underlying the sands, as at Erith, would probably offer some resistance to the upward passage of water, and so assist in preventing the water from escaping inland from the chalk.

As to the possible Quantity of Infiltration.

Assuming the aforementioned estimate of Mr. P. W. Barlow's (page 86) to be a fair one, and assuming that this 60 million gallons may find its way out at low tide along 20 miles of river bank; if land under the river banks for a distance of 50 miles permitted percolation to take place at the above ratio, we should find a leakage of 150 million gallons per diem. This leakage may be presumed to have taken place below mean tide level, that is, for 12 hours out of 24; and from the saturation level in the marsh there would have been, during this period, a mean difference of, say, 5 feet, occasioning the leakage, or perhaps a little more. If a mean difference of levels of 5 feet occasions a leakage of 150 millions per diem, a difference of level of 10 feet, operating for 24 hours per diem, might occasion a leakage of 600 million gallons per diem.

I question somewhat whether this mode of argument, based on Mr. Barlow's estimate, is justifiable, and would rather regard the difference between the mean

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tide level and the *then* saturation level in the marshes as determining the rate of flow. As this cannot be discovered, we therefore cannot argue on this basis. Information and evidence as far as it goes, however, points to the likelihood of percolation in large quantities.

Out of the 100 million to 200 million gallons of water pumped daily from the London Basin, quite a large proportion is derived from the low-lying land in the neighbourhood of the Thames. The amount so derived has greatly increased during the last 10 or 20 years, and is likely to further increase in the near future. The pumping, therefore, that may have to be resorted to to keep down the "saturation levels," under the altered conditions, might be made use of for the supply of water for industrial and other purposes. If it were not so used, the pumping as at present carried on would help materially to keep down the "saturation levels."

It would appear that the Thames Embankment through London prevents infiltration, as it shuts the gravel and other permeable beds from contact with the river. I gather that Mr. Hennell thinks the Metropolis, or that portion of it differently shaded in his map, may be drained of percolating water by the present system of drainage, so that it may not be necessary to make any provision for laying special drains for the removal of water filtering in. But whether this be so or not, the additional water which would find its way down these drains as the result of the water filtering in from permanent high-water level, would all be so much additional water to be pumped to the level of the river, as referred to in his Report and estimated (Section). Having regard to the information at our disposal, I should judge that the amount of water percolating would be likely to amount to anywhere from comparatively insignificant quantities up to 20 million gallons per mile of river wall per diem, according to situation.

As to General Conclusions.

I presume we are at the moment concerned with the question as to whether infiltration is likely to present insurmountable difficulties. This is a question on which it is quite impossible to form an opinion without further evidence. That large volumes of water would pass in from the river at different points there is, in my opinion, no reason to doubt. The question still remains, how much water would have to be removed?

This is a question to be dealt with by the Engineers or a Board of Trade enquiry. I can understand that the provision suggested by Mr. Hennell might deal effectively with the water in the ditches and the marsh land generally; but I am of opinion that special provision will have to be made for keeping down the "saturation levels" in the chalk, and other pervious strata, especially in the low-lying land where the chalk is bare. Also in some parts of London, in the gravel, similar difficulties may arise. Adequate recommendations could only be made after the most exhaustive enquiries.

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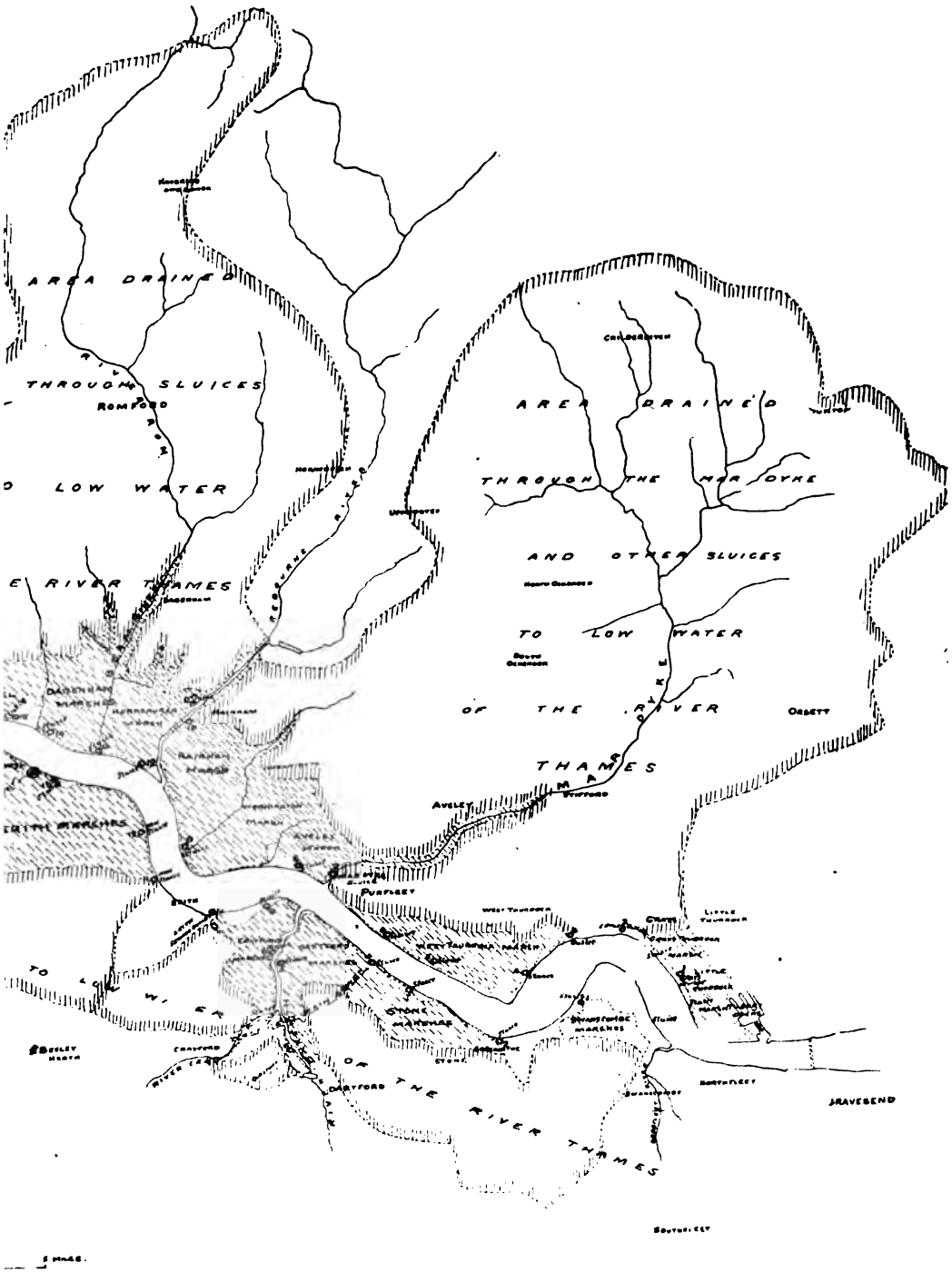

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SECTION XVI.

THE RIVER WALLS AND LOW-LYING LANDS, AND WORKS NECESSARY FOR DEALING WITH DRAINAGE AND SEWAGE.

By T. HENNELL, M.Inst.C.E.

I have to report on the work that would require to be done in raising the drainage water or sewage from the low lands in order to maintain a continuous high-water in the river.

I have prepared a Map showing the extent of these low lands, and the situation of the Pumping Works, which I think would be necessary; also a detailed Schedule, with particulars, of each. These accompany this Report.

The marsh lands in Kent and Essex cover 26 square miles of country, all of which are from 6 to 8 feet below high-water level. These marshes are now drained by a system of dykes leading to sluices in the river walls 3 to 6 feet above low-water level.

A considerable area of higher ground further inland is also, especially in Essex, drained through the same marsh dykes and sluices. The Map shows the extent of land so drained to each marsh.

It will be necessary to lift all the rain water now draining off these areas by pumping it over the banks to the high-tide level; and this must be done in wet weather and after storms, at a rate of speed that will prevent the land from being flooded more often than now. Sufficient pumping power must, therefore, be provided for this purpose, and worked whenever required.

The average annual rainfall over the district draining to the part of the river now under consideration is 25 inches, and after deducting 14 inches, the usual proportion for evaporation and absorption, there will remain 11 inches to be drained off during the year.

Eleven inches of rain on 130 square miles will represent about 20,730,000,000 gallons of water, or 56,800,000 gallons a day during 365 days.

To pump this volume to a height of 15 feet, if it came regularly and were all brought to one place, would require the exertion of about 160 horse power—comparatively a very small matter.

But of the 25 inches of rain falling in 12 months, 8 inches may, at any time, come in one month, 6 inches in one week, and upwards of 3 inches in one day. On the 23rd of July, 1903, 4 inches of rain fell in one day at Dartford, and more than 3 inches over the whole of the lower Thames Valley.

And if these volumes of water have to be lifted into the river, they must be dealt with, of course, as they come; not necessarily on the day the rain falls, but within a reasonably short time afterwards.

In short, the water which comes down the marsh dykes to the river banks must be pumped out with sufficient rapidity to put the landowners and farmers in no worse position than they are now with respect to the saturation or occasional flooding of their land.

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In the writer's opinion this object would be effected by the raising in one day when required of a volume equal to half-an-inch of rain on the marshes and one-eighth of an inch on the contributing uplands.

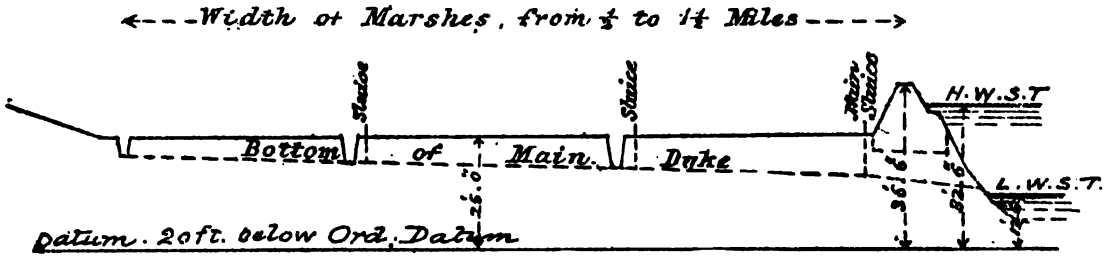
The absorption into the soil is much greater on the latter when already saturated. It also flows down more slowly from the higher ground, especially the more distant places.

On this assumption, 372 million instead of 56 million gallons must be raised on certain days in each year, perhaps daily for a week or more on occasions.

And the places where the work has to be effected must be, with possibly some exceptions, precisely where there are existing sluices or outlets below high-water.

The marsh lands are, as is well known, intersected by a system of dykes, which, although to travellers on the railways they may appear to contain stagnant water, are, in fact, carefully constructed and maintained with regular inclinations in certain directions, so that the water, if not held up by intermediate sluices, will always be slowly travelling toward the main sluices on the banks of the river.

The section below shows the general position and level of the marsh lands with respect to the river. See Fig. 31



GENERAL SECTION OF THE ESSEX & KENT MARSHES

Fig. 31.

These latter sluices are at varying distances apart, averaging generally half to three-quarters of a mile; but even when they are nearer than this it would often be difficult, without considerable alteration of the marsh drainage, to bring the water to fewer points and so combine two or more stations for the purpose of pumping it out.

Practically, there must be a pumping station at nearly every sluice or outlet; although at many of them the work to be done will be generally very little, and in dry weather sometimes none at all for several weeks, while water is being penned back at higher points.

At an average sluice, in order to provide for the maximum duty, duplicate engines would be required, each of about 12 horse power, and provision must be made for their being both worked for 20 hours daily when required. Nevertheless, one only will do the average work in about four hours.

Many of the sluices are in inaccessible places, there being sometimes no road of any kind within two miles of the spot. The pumping stations must, therefore, be got at generally either on foot by the river wall, or by water. A small landing stage should consequently be provided at each station, and also the necessary stores and housing accommodation for at least one engine-man.

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And a system of reliefs must be arranged so that assistance can be sent to every station within a few hours whenever there is heavy rain.

Some few of the pumping stations will be considerably larger than others, and these, in proportion to the work done, will be less costly both to construct and maintain. In the neighbourhood of the Mar Dyke Sluice, for instance, at Purfleet, there must be a station providing about 250 horse power, and in some few others nearly half this amount. Forty-seven pumping stations in all are required in Essex and Kent for raising the waters of the low-lying lands between Gravesend and Greenwich.

There are in London also considerable areas of ground below high-water level, but these are in almost all cases drained by the Metropolitan sewers, which, unlike those of the outside authorities, are made to convey rain water from streets and roofs. The combined sewage and rain water is received into the sewers, pumped at various places, and finally, after partial treatment, delivered into the river at the main outfalls at Barking and Crossness, the greater part of it above high-water level.

But when the quantity of rain is very large the main sewers run full, and the excess passes through old sewers, now acting as overflows, directly to the river at various points in London itself. Several of these are incapable of delivering at high water, and therefore the sewage at that time backs up and stands in the sewers. This arrangement is unsatisfactory for many reasons, and the London County Council are from time to time constructing new overflows with pumping engines to deliver at the higher level. (*See* Reports of Main Drainage Committee, L.C.C.)

A proportion of the sewage at Barking and Crossness would require to be further lifted on account of the constant high water, but this proportion will be small as compared with the whole. And some additional pumping works would also be required at the overflows, which would, of course, have to be under the supervision of the London County Council.

In addition to discharges to sewers, many riverside owners have small flap outlets to the river below high water. Although there are doubtless a great number of these outlets in different parts, their use is, under Conservancy Regulations, much less general than it used to be, and it could hardly in any instance cause serious expense to close them and make connection to the sewers instead.

Above London there are some small areas below high water at Chiswick and Twickenham, in Middlesex; and at Barn Elms, Mortlake, Kew, Richmond, and Petersham, in Surrey. And there are many other places where, if high tide is continuously maintained, the water in the surrounding soil, if not kept down by pumping will rise very nearly to the surface, surround the foundations of houses, and greatly depreciate the properties. This can only be avoided by constructing sub-soil drains leading to pumping wells, and so from time to time pumping water out and keeping down the saturation level. For this and other purposes I consider that 20 more pumping stations (shown on the Map and Schedule) will be necessary West of London. None of these, however, will require to be of considerable size, except the one at the Beverley Brook, which drains a large area of country.

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It will be observed that, in addition to the low-lands drainage, pumping of sewage has to be provided for at several local sewage works outside London, viz.: at Grays, Barking Town, and East Ham, in Essex; at Dartford Marshes (for the West Kent Main Sewage Works) and at Erith, in Kent; and at Chiswick, Middlesex; and Kew, Surrey (for the Richmond Main Sewage Works). At all these places the sewage, or sewage effluents, are now passed into the river either wholly or partly below high water. At all but two of them, however, there are pumping works already in operation, to which additions only will be required for a second pumping of part of the effluents after treatment.

I have made detailed estimates of the power that would be required for all the above described pumping works, viz.: (omitting the Metropolitan sewage) about 3,300 horse power; and of the first cost of the works, which would amount to about £474,400.

It must, however, be observed that these calculations are made on the assumption that rain water alone has to be dealt with on the marshes, and not any part of the water of the river passing through or under the river walls. This subject is referred to later, and is also dealt with elsewhere by Mr. Clayton Beadle.

I am quite satisfied, both from observation and from information kindly furnished me by others, and especially by Mr. Hurtzig, M.Inst.C.E., who has charge of the marshes in Kent, that, except in cases of accident, no water ever passes through the river walls. They are everywhere of ancient date and very well made, consisting of embankments on a wide base with a core or centre wall of clay. But these walls are carried down about 2 feet only into the ground.

There are occasional slips in the banks, which are now repaired between the tides; and there have also been, as is well known, from time to time, breaches causing serious inundations; but these have been generally brought about by extraordinary high tides, which can hardly occur again under the proposed altered conditions.

The consequences of any breach while the tide is continuously high, and without the means of access as before to the river side of the banks for repair, would, however, be so serious that I have no hesitation in saying, in my opinion, the strengthening of the walls in many places must be considered a necessary part of any Barrage Scheme.

I am of opinion that a parallel inner wall ought to be made wherever there is now an ordinary wall not less than 10 feet in total height; that is to say having a pressure of 5 or 6 feet depth of water always against it, which pressure is necessarily liable to be increased to 9 feet during an extraordinary tide.

This is a work whose cost can be easily calculated, and it will, in fact, be less than at first appears, for on detailed examination it will be found that the existing walls are, in fact, already strengthened or supported throughout nearly three-fourths of their entire length.

First there are in many places for long distances saltings or salt marshes between the wall and the river, the surface of these saltings being approximately that of high water in the river. These saltings are generally covered only by the highest ordinary or by extraordinary tides.

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Again there are many places where the walls have been widened or supported on the land side by ground made up for purposes of the riverside works, or by material which has been brought in barges and tipped on to the marsh lands.

The last-named process has been going on very rapidly during the last few years, so much so that the Greenwich and some of the Essex marshes are in this way gradually disappearing.

At Dagenham, for instance, a mile of the river frontage is now continuously occupied, besides many shorter lengths in neighbouring places.

There are thus three conditions to deal with:—

1.—The ordinary river wall, where a separate inner wall will be required and should be constructed in the usual way with a puddle core and trench carried down some distance below low-water level. (See Fig. 32.)

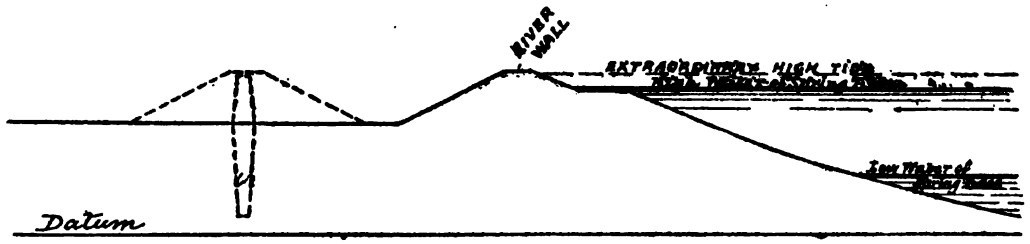

Fig. 32.

2.—The wall protected on the river side by saltings, where an inner wall is not necessary, but the puddle wall and trench to prevent infiltration may be made on the inside of the existing wall, and the excavated material used to widen the bank. (See Fig. 33.)

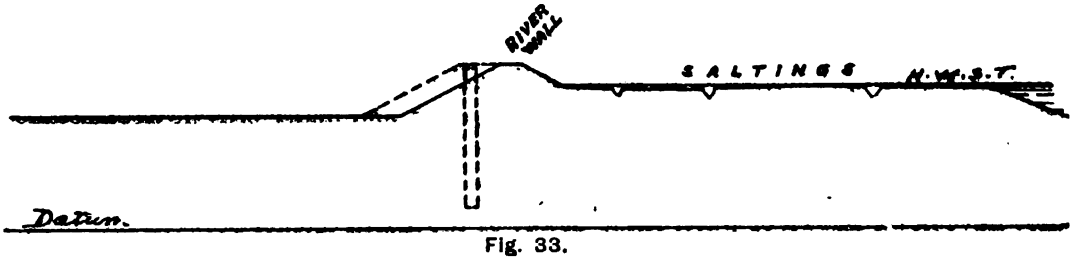

Fig. 33.

3.—The wall originally constructed as Fig. 32, but since widened or supported on the land side by made ground, tipped or otherwise. Here if the widening is of no great width, the puddle will still be necessary; but if the tipped or banked-up material extends for a long distance, infiltration through or under it will practically be impossible; therefore, no further work is required. (See Fig. 34.)

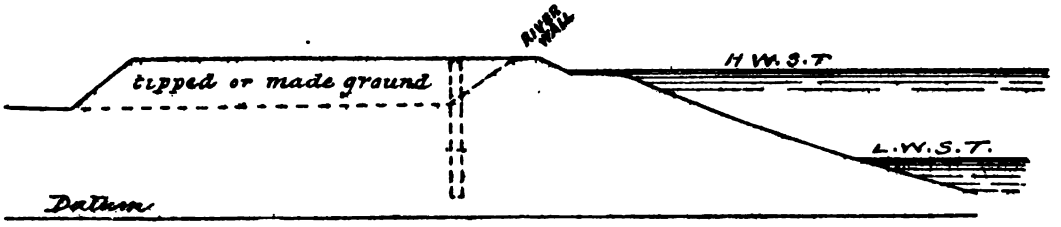

Fig. 34.

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The total length of the walls or banks is about 51 miles, including the tidal creeks.

Inner walls, as described, will have to be constructed, as nearly as can be ascertained, for length of, in all, 15¼ miles, and puddle walls or trenches at side of the existing walls for 22¾ miles in addition.

There is no reason, in fact, why the pumping power should not be sufficient to lower the "saturation level," and thus dry all these lands for building purposes and factories.

Estimated Cost of Pumping Works and Walls.

The following figures represent approximately the cost of the various works, as far as they can be estimated without more detailed surveys :—

Protection to River Walls :—

Inner wall and puddle trench—15¼ miles at £25,000 per mile	£383,300
Puddle trench to existing wall—22¾ miles at £18,000 per mile	408,000

Pumping Works :—

For the drainage of the Essex and Kent marshes, and raising sewage at five outfalls to the river	355,500
For the drainage of the low lands in Middlesex and Surrey, and raising sewage at two outfalls	118,900
Total	£1,265,700

The annual expenses of maintenance and working the pumps are estimated at £33,000. This does not include any estimate of additional cost of dealing with the Metropolitan Sewage.

The existing puddle wall 2 feet in the ground does not, of course, prevent the river water from passing under it wherever the sub-soil consists of gravel or other easily permeable material. Such passage is, however, slow, and under present circumstances there are only occasional means of detecting it.

Two, out of four, of the Engineers now in charge of the marshes have told me that they have never known of water rising in any of the marsh ditches between the tides, or even during extraordinary high tides. But the water level in these ditches is generally about the level of mean tide, 10 feet below high-water of springs, and 13 to 14 feet below the highest extraordinary tides. Therefore, for about one hour twice in every 24, there is a pressure of from 8 to 10 feet and sometimes more on the underground water contained in the gravel or other subsoil under the banks, and this pressure does not during that time produce any appreciable effect. This may, of course, be because there is a coating of mud in the river which prevents the water getting in, or a layer of clay or other impermeable material which prevents its rising; or else the process of infiltration is so slow that a pressure continuing during six hours, increasing from 0 to 10 feet and diminishing again to 0, is insufficient to force the water through; that is to say, it begins to run out before it has had time to rise to an appreciable height.

The last is no doubt generally the correct solution, as there must be places where mud and clay are both absent.

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Wherever there is now a rise and fall, to however small extent, of underground water during tides, the same water will, if the river is constantly high, continue to rise to 8 or 10 feet above its present average level; that is to say, in the case of the marshes to above the ground; and this can only be prevented by pumping at the places I have scheduled.

The difficulty consists in ascertaining beforehand the volume which would have to be pumped. So far as this consists of water derived from rain it can be easily estimated; but if there is other water coming in from the river as well, it will be hardly possible to arrive at the quantity without actual trials.

I had thought that possibly, by means of puddle walls carried down to an average depth of 20 feet—say, 5 feet everywhere below low water, and occasionally deeper—infiltration under the walls might have been avoided altogether.

I find, however, on further investigation that these walls would have to go down often 30 feet or more; in fact, some borings show no reliable impermeable stratum between the surface and the chalk at depths of 120 or 150 feet. (*See* cross-sections of river-bed, page 22). But the recorded results of single borings are seldom to be entirely relied upon, and the few at places sufficiently near the river, which I have been able so far to obtain, form altogether insufficient material to estimate from.

A trench to be dug to 5 feet below low-water level and filled with puddle will be by no means expensive, but whenever it becomes necessary to dig much deeper than this in wet gravel or similar substance, the cost will increase very rapidly, and it may be better to provide for pumping increased volumes of water rather than undertake such a work.

The conclusion I have come to is that it will not be possible, by means of puddle walls or otherwise, to avoid infiltration altogether; and that it may therefore be necessary to provide at all the proposed pumping stations in my list between Greenwich and Gravesend some increased power in order to deal with it, and probably where they are far apart to put down some intermediate stations in addition; and also, of course, to work the pumps more frequently or during longer hours.

The stations as scheduled are designed to deal with excessive flows of rain, and to be worked continuously on rare occasions only, the average duty being possibly one-tenth only of the maximum in times of flood. But any additional pumping due to infiltration will be a constant quantity, the same in all weathers throughout the year.

As to the practicability of draining by pumping engines large areas of land below the natural drainage level, and thus naturally marshes or slob lands, the following instances may be cited:—

In the valley of the River Po 600,000 acres have been drained by pumping.

In the South of France similar large areas have also been drained by pumping.

In Holland, before draining Lake Haarlem, the rainfall on 75,000 acres of polders was lifted by 261 large windmills and drained to the sea: total horse-power, 1,500.

Holland is gradually sinking, and very large areas are below sea level, so that reliance has to be made on pumping for the entire drainage of these areas by windmills and pumping engines.

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SCHEDULE OF PUMPING AND OTHER WORKS REQUIRED TO LIFT TO HIGH-WATER LEVEL THE DRAINAGE WATER AND SEWAGE NOW ENTERING THE RIVER AT LEVELS BELOW T.H.W. BETWEEN TEDDINGTON AND GRAVESEND. (NOT INCLUDING THE METROPOLITAN DRAINAGE, AND NOT INCLUDING PROVISION FOR ANY RIVER WATER PASSING THROUGH OR UNDER THE WALLS.)

No.	Situation.	Drainage, &c., to be Dealt with.	Works Required.
	North Side, commencing at Gravesend (County of Essex).		
1.	Grays Thurrock Marsh	Portions of Grays Thurrock and Little Thurrock Marshes (about $\frac{8}{10}$th square mile) and sewage of Grays Urban District. Pop., 14,000.	Pumping Station at River Wall, with separate pumps for sewage effluents, alteration of Marsh Drain to bring to common point.
2.	Town of Grays	Five Drain Outlets, to be brought together.	Pumping Station on Wharf, about 400 yards deep drains.
3.	Thames Cement Works, Grays.	Drain Outlet	Small Pumping Station on Wharf.
4.	Sluice near Stone Ness	The West Thurrock Marshes, $1\frac{1}{2}$ square miles, with upland area contributing.	Pumping Stations at River Wall at each of the three points.
5.	,, at Northfleet Co.'s Pier.		
6.	,, at Thames Paper Mills, Purfleet		
7.	Mar Dyke Sluice ..	The Mar Dyke, which drains about 36 square miles of upland area.	Pumping Station (probably about 250 H.P.).
8.	Sluice in Aveley Marsh	Rainham, Wennington, and Aveley Marshes together, 3·9 square miles and uplands.	Pumping Stations at River or Creek Walls at each point.
9.	,, in Rainham Marsh		
10.	,, E. Side, Rainham Creek		
11.	,, near Red Bridge, Rainham	Barking Level, Ripple Level, Dagenham and Hornchurch Marshes, in all 4·8 square miles, and contributing upland area of 32 square miles.	Pumping Stations at River or Creek Walls at each point.
12.	,, at "Old Man's Head"		
13.	,, at Beam River (discharge from two Sluices to be brought together)		
14.	,, at Dagenham Dock		
15.	,, at Horse Shoe Corner		
16.	,, (Tower) Ripple Marsh		
17.	,, at "Barking Point"		
18.	Pipe Outlet near Damper's Dock		
19.	Sluice at Mayes Brook		
20.	Barking Town Sewage Works.	Sewage of Barking Town Urban District. Pop., 25,000.	Additional pumping at existing works for sewage effluent.
21.	Sluice, White Gate Bridge, Barking.	Marsh Area draining to Back River.	Pumping Station adjoining road.
22.	East Ham Sewage Outfall.	Marsh Area draining to two Sluices; also sewage of East Ham Urban District. Pop., 130,000.	Pumping Station, with separate pumps for sewage effluent. Alteration of Marsh Drains, including Syphon under Back River.
23.	Sluice Gallions, W. Side Barking Creek.	Part of East Ham Level.. ..	Pumping Station at Wall of Creek.
24.	Sluice, Albert Dock Cut	Part of East Ham Level, including Beckton.	Pumping Station at River Wall.

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No. Situation.	Drainage, &c., to be Dealt with.	Works Required.
North Side—continued—		
25. Gas Works Sluice, West Ham Corporation ..	Portion of Marshes south of Victoria and Albert Docks.	Pumping Stations on Wharves at each point.
26. Pods Elm Sluice, West Ham Corporation ..		
27. Midland Sluice, West Ham Corporation.	Portion of Marshes draining to the Victoria Dock Cut.	Pumping Station in G.E. Railway Yard.
28. West Marsh Sluice, West Ham Corporation.	Portion of the West Marsh, not built over.	Pumping Station adjoining road, Canning Town.
29. Dr. Taylor's Sluice, West Ham Corporation.	Portions of Abbey Marsh and Mill Meads, not built over.	Pumping Station on vacant ground and Syphon under Rivers from Mill Meads.
30. Stratford Marsh, West Ham Corporation (Bow)	Portions remaining uncovered of Stratford Marsh, &c.	Pumping Station at or near Bow Road.
In County of London.		
31. Hurlingham	Hurlingham House and Grounds, &c.	Small Pumping Station.
32. Fulham Palace	Palace and Grounds, &c., now draining to the Moat.	Small Pumping Station.
In County of Middlesex.		
33. Chiswick Sewage Works	Sewage of Chiswick Urban District. Pop., about 35,000.	Additional pumping at existing works for sewage effluent.
34. Sluice, Grove Park Farm	Drainage from Chiswick House Lakes and surrounding area.	Pumping Station at River Bank.
35. Grove Park	Drainage from Lake and surrounding area.	Pumping Station and sub-soil drains leading to it.
36. Strand-on-the-Green ..	Drainage from Back Lane, &c.	Pumping Station near River and sub-soil drains.
37. Town of Brentford ..	Three Drain Outlets, to be brought together.	Pumping Station at Wharf and drains to same.
38. "Old England"	Drainage from Sion Park Lake and surrounding area.	Pumping Station near River and sub-soil drain through meadows.
39. St. Margaret's, Twickenham.	Drainage from Lake and surrounding area.	Pumping Station and sub-soil drains.
40. Marble Hill Estate, Twickenham.	Drainage from Park and surrounding area.	Pumping Station in Park (L.C.C.) and sub-soil drains in adjoining properties.
South Side, commencing at Gravesend (County of Kent).		
1. Bell Wharf, Swanscombe	Swanscombe and Botany Marshes.	Pumping Station at River Wall. Alteration of drains from Botany Marsh.
2. Pipe Outlet, Greenhithe	Eastern part of Stone Marshes	Pumping Station adjoining Road.
3. Sluices near Little Powder Creek.	Greater part of Stone Marshes	Pumping Station on River Wall and alteration of Marsh Drains to bring to one point.
4. West Kent Sewage Outfall.	Sewage of the West Kent and Darenth Valley Main Sewerage Districts. Pop., 150,000.	Pumping Station at the Works to pump from tanks into River. (No pumping done now.)
5. Sluice, E. Side Dartford Creek.	Dartford Marshes	Pumping Station on Wall of Creek.
6. Dartford Old Sewer Outlet.	Surface Water of Streets in Dartford and overflow from Sewers.	Pumping Station at Lock on Creek.

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No	Situation	Drainage, &c., to be Dealt with.	Works Required.
South Side—continued—			
7.	Floodgate on River Cray	Marshes between the Rivers—Cray and Darenth.	Pumping Station at River Wall, and cut to connect from Stanham Brook.
8.	W. Side Dartford Creek	Part of Crayford Marshes ..	Pumping Station at River Wall.
9.	Salting, near Crayford Ness.	Part of Crayford Marshes ..	Pumping Station at River Wall.
10.	Erith Sewage Works ..	Sewage of Erith Urban District. Pop., about 30,000.	Some additional pumping required at the existing works.
11.	New Sluice, Erith Gas Works	Plumstead and Erith Marshes, total area, $4\frac{9}{10}$ square miles.	Pumping Stations at River Walls at each point.
12.	New Sluice, Callender's Works		
13.	Sluice near Guano Works		
14.	Sluice near Crossness Point		
	In County of London.		
15.	Sluice near Tripcock Tree		
16.	Sluice, Woolwich Arsenal		
17.	Pipe Outlet, near Charlton Wharves.	Portions, still uncovered, of Greenwich Marshes.	Pumping Station at River Wall.
	In County of Surrey.		
18.	Beverley Brook Sluice Gates.	Drainage of Barn Elms Park, &c., and considerable inland area, about 19 square miles, in Surrey.	Pumping Station in Grounds near Towpath, and drain from Sluice at North end.
19.	Pipe Outlet at Hammersmith Bridge.	Surface-water Drains in Barnes.	Pumping Station at Towpath.
20.	Pipe Outlet at Ferry Road.	Surface-water Drains in Barnes.	Pumping Station and drain from W. Middlesex Filter Bed Outlets.
21.	Pipe Outlet at Barnes Terrace.	Surface-water Drains and overflow from Sewers.	Pumping Station.
22.	Near Ship Inn, Mortlake	Surface-water Drains and overflow and drainage from low lands.	Pumping Station and connecting drains.
23.	Richmond Main Sewage Works, Kew.	Sewage of the Richmond Main Sewerage District, including Richmond, Petersham, East Sheen, Kew, Barnes and Mortlake. Pop., 60,000.	Additional pumping required for effluents at the existing works.
24.	Near Kingston Dock, Kew.	Drainage from low lands ..	Pumping Station and connecting drains.
25.	At Botanic Gardens, Kew.	Drainage from Lake, Gardens, and part of Richmond Deer Park.	Pumping Station and connecting drains.
26.	At Richmond Railway Bridge.	Drainage from part Richmond Deer Park, &c., and overflow from Sewers.	Pumping Station and connecting drains.
27.	At Petersham Meadows	Drainage from low-lying ground	Pumping Station and connecting drains.

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SECTION XVII.

THE RIVER WALLS.

From "EAST LONDON" by SIR WALTER BESANT.*

Sir Walter Besant has written in his wonted interesting style about this wall and part of his description is well worth quoting. After describing it as "the wall which runs all along the north bank of the river and is carried round the marshy Essex shores and round the Essex islands, and which also protects the south bank whereon the marsh prevails," he goes on to say :—

No one knows when this wall was built. It was so early that all record of its building has been lost. It is the wall by which the low-lying marshes of the Thames, once overflowed by every high tide, were protected from the river and converted into pastures and meadow-land and plough-land. . . . It has been a work of the highest importance, to London first, and to the country next. It has converted a vast malarial belt of land into a fertile country and it has made East London possible, because a great part of East London is built upon the reclaimed marsh now drained and dry. In order to understand what the wall means, what it is, what it has done and what it is doing, we must get beyond the houses and consider it as it runs along the riverside with fields on the left hand and the flowing water many feet higher than the fields on the right.

Sir Walter then explains how to get at the wall. You take the train to Barking and following the banks of the little River Roding past some chemical works until you reach its confluence with the Thames and, finding yourself at the wall, "you step out upon the most curious walk that one may find within the four seas that encompass our island."

No one even walks upon this wall : once beyond the chemical works we are in the most lonely spot of England : no one is curious about it, no one seems to know that this remarkable construction extending for about a hundred and fifty miles, even exists : you will see no one in the meadows that lie protected by the wall ; you may walk mile after mile along it in a solitude most strange and most mysterious.

The antiquity of the wall and the weirdness of the scene evidently impressed themselves on the author, for he proceeds to enlarge on the theme in his imaginative and inimitable manner. It is only consideration of space prevents our reproducing the passage. But further on we read :—

The wall is about 15 feet high : at the base it is perhaps 30 feet wide, the sides slope towards the path on the top which is about seven feet across ; the outside is faced with stone ; the inside is turfed. Looking south, the river runs at our feet ; on the land side the fields which have been rescued from the tidal flow, they are obviously below the level of the river ; one understands, looking across them, how the river ran of old over these flats, making vast lagoons at high tide. It is useful to see the fall recorded in a book or on a map, but here one sees that it really must have been so. Gradually as one passes along the wall and looks landward the history of the reclamation of the marsh unfolds itself; we see in places, here and there, how mounds which are lines of former embankments, these are not parallel with the river, they are thrust forward protected by banks at the side; small pieces reserved by some dead and gone farmer who was rewarded by having as his own with no rent to pay the land he had snatched from the tide. Perhaps it was

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long before rent was thought of; perhaps it was easier to build the bank and to take a slip of the foreshore and the marsh, with its black and fertile soil, than it was to cut down the trees in the forest and to clear the lands; perhaps these embankments were constructed by the lake dwellers who made their round huts upon piles driven into the mud, and after many thousands of years made the discovery that it was better to be dry than wet, and better to have no marsh fevers to face than to grow inured to them.

Sir Walter Besant then proceeds to consider the question of the antiquity of the wall, and, after citing in order a number of facts as to British intercourse with the ancient Gauls and Romans, arrives at the following general conclusions :—

For centuries there had been a constant intercourse between the Gauls and the Southern Britons; trading centres had been established, notably in Thorney Island, at Southampton, at Lyme, which was afterwards an important Roman station, and at Dover. When the ships began to sail up the Thames, the superior position of London was discovered, and that port quickly took over the greater part of the trade by the Thorney route. When London grew, it became important to reclaim the malarious marsh and the wasted miles of mud. Some kind of embankment, perhaps that old kind with trunks of trees, was constructed. At first they put up the wall on the opposite side, which the Saxons afterwards called the South Work (Southwark), meaning the river wall and not a wall of fortifications; then they pushed out branches on the northern side and carried the wall gradually, not all at once but taking years, even centuries, over the work, down the Thames along the Essex shores and round the mud islands, but the last not till modern times.

Sir Walter then describes a place at the end of the Essex wall, five or six miles from a railway station, called Bradwell (Broad wall), where are the remains of a Roman fortress and a chapel dedicated to St. Peter, a little village church at West Thurrock and various other churches or chapels on or besides the wall. All these chapels he is inclined to think were erected so that prayer might be said in them for the preservation of the wall.

The maintenance of the wall has always been a costly business, the tides find out the weak places and bore into them like a gimlet that grows every day larger and longer and more powerful. For instance, near the junction of the Lea and the Thames, a monastery called the House of Stratford Langthorne was once overwhelmed through a breach of the wall. Similarly, near Barking Nunnery, part of the wall broke down in the time of Richard the Third. Fifty years later the Plumstead marshes were drowned by the breaking of the wall. In 1690 the Grays Marsh lower down the river was overflowed by the same accident; in 1707 the wall gave way at a place called Dagenham; it took nearly twenty years to repair the wall, which was carried away time after time; the receding tide carried out into the bed of the river so much earth that a bank was formed in mid-channel and it seemed as if the river would be choked. At last it was found possible to construct a wall which would stand the highest tide.

A curious bit of local history then finds place in the book we are quoting from :—

If we walk along this part of the wall we observe a large black pool of water, this was left behind when the wall shut out the river; the lake still remains and is full of fish, and on Sundays it is surrounded by anglers who stand all day long intent upon expectations which are seldom rewarded. Out of this lake and its fishing originated the Ministerial whitebait dinner. It began when the occupant of a house beside this lake invited William Pitt to dine with him in order to taste the eels of the pond and the whitebait of the river. Pitt brought other members of the Cabinet and the dinner became a yearly institution; the place was transferred from Dagenham to Greenwich and the Ministerial whitebait dinner was held every year in June or July until ten or twelve years ago (*i.e.*, 1890) when the pleasant institution was stopped.

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The author adds in conclusion that the wall was, in his opinion, put up here and there as occasion or necessity served, and that some of the land was rescued strip by strip each time by a new wall. It has converted miles and miles of barren swamp into smiling meadows and fertile farms, and even now there are broad stretches of mud along the Essex shore which might be reclaimed with as much success as has blessed the efforts of the Dutch in their lowlands.

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SECTION XVIII.

THE SANITARY CONDITIONS OF THE RIVER.

By W. J. DIBDIN, F.I.C., F.C.S., *Vice-President of the Society of Public Analysts.*

PAST IMPROVEMENT OF THE TIDAL WATERS.

From time immemorial the refuse of the Valley of the Thames has found its way sooner or later, directly or indirectly, into the waters of the River Thames, and this will continue to be the case until the geographical conditions shall alter. A consideration of this elementary fact in its several bearings will greatly assist one in forming an idea as to the relation of the various factors which govern the whole process of the destruction of the refuse matters, and the enormous quantity of organic as well as mineral matter thus disposed of, which disposition over such prolonged periods has left relatively no trace, the waterway of the river being maintained and the formation of mudbanks merely keeping pace with the denudations according to local conditions, as these are affected by dredging, tidal set, &c. The natural drainage necessarily carries into the river enormous quantities of refuse from manured lands, &c., as well as that from the various towns situated within the watershed of the river; so that the water-carried debris, apart from the question of the sewage of the Metropolis, must be considerable. The consideration of the simple fact that so small a quantity of suspended matter in the water flowing over the Teddington Weir as one grain in each gallon will, even in the driest summer weather, equal about 15 tons per day, will enable us to follow the position in some degree. In times of storm and floods the suspended matter in this upland water may be equal to 5,000 tons of dry matter per day, whilst on another day the quantity may not exceed 5 tons of dry matter; but taking the average (over the month of February, 1880) the quantity was 444·9 tons of dry matter per 24 hours. During this period the total quantity of suspended matter per gallon equalled 3·482 grains, the organic matter in this being equal to 0·499 grains. Before London assisted to swell the volume of this contribution to the estuary of the Thames, the whole was disposed of by the agencies naturally at work in the river without the slightest nuisance or inconvenience. It was only when London offended Nature by sending the whole of its offensive refuse into the Thames between the Bridges at all states of the tide that a stagnant accumulation took place and the river became filled with corruption. In consequence of most of the sewers having to pass under the low grounds on the margin of the river their contents were discharged at the time of low water only. The sewage was consequently carried up the river by the rising tide and brought back again by the falling tide to mix with each day's additional supply, with the result of an intolerable state of affairs arising. To remedy this condition of things the Metropolitan Board of Works was created, and the sewage was intercepted from the river and carried to the two main drainage outfalls at Barking Creek and Crossness, where it was stored until high-water and then released on the first of the ebb tide, the discharge continuing until the half-ebb tide, when the reservoirs were empty. The

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sewage was thus carried away into and down the river with the vast flood of tidal water. This process was found to answer for some 15 years, when, in consequence of the increase in the volume of the sewage the reservoirs filled up too rapidly and overflowed into the river at all states of the tide, with the result that the former condition of things which prevailed between the Bridges was repeated at and about Woolwich, &c. It now became evident that the better plan would be to remove the grosser solid matters from the sewage, which were the chief cause of the trouble, and thus free the river from the undue burden cast upon it, merely relying on the purifying power of the stream to deal with the matters dissolved in the water and the finer divided matters in suspension. This was done with the result that up to the present time all nuisance has disappeared, and so far as smell or sewage deposits are concerned there might be no sewage outfalls.

The good work has been undoubtedly helped by the general efforts which have been made to prevent the discharge into the river of many contributions of an offensive character; and, as much yet remains to be accomplished in this direction, it may be reasonably expected that in the future this help will be greatly extended. Nevertheless, it cannot be maintained that all that can be done has been done. When the writer proposed the scheme at present in use to the Royal Commission, in 1884, he pointed out that as our knowledge of sewage treatment increased, doubtless it would be found possible to still further improve the quality of the effluent at a reasonable cost. This forecast has proved correct, and there is no reason—other than the financial one—why these further means should not be at once put in action. In fact, this is not so great a burden as might be supposed, because the saving which would be effected in the present working expenses would go a long way to pay the annual charge for interest and repayment of loan on the expense of the necessary plant. When this point is once fairly grasped by those in authority further progress may be expected. In this connection it may be pointed out that when various methods of treating the sewage were under discussion, it was fully anticipated that the capital cost would be at least £10,000,000. The scheme actually adopted cost about £1,000,000 only, and we are now in the position to say that the whole of the additional plant required to bring the works up to date would probably not cost more than another million; thus effecting the complete realization of the ideal scheme for about one-fifth of the amount originally contemplated by even the most economical of the critics.

Present Condition of the Tidal Waters.

The present condition of the tidal waters, although sufficiently pure to prevent nuisance, is yet not sufficiently so to encourage the presence of fish in all parts at all states of the tides. For instance, fish require at least a quantity of dissolved oxygen in the water equal to 50 per cent. of that which is naturally present in a well aërated water; otherwise they will not thrive. The diagram (Fig. 35, p. 116) shows that the average in the water at Teddington will be about 80 per cent. of the total possible, whilst at London Bridge it will fall as low as 10 per cent., rising again at Southend to 60 per cent. It is, therefore, clear that there is a long stretch of water between Teddington and the lowest reaches of the river which contains such a small quantity of dissolved

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oxygen as to render it incapable of supporting fish life. Similar researches on the character of the river at 15 points of observation have demonstrated that the area of maximum pollution varies in position, according to the season, from Hammersmith in the summer months to below Barking Creek in the winter months, its exact position being due to the influence of the rainfall. These considerations point to the conclusion that before the water has been purified so that a healthy fishery can again arise in the Thames as a whole, the further means of purification of the London sewage

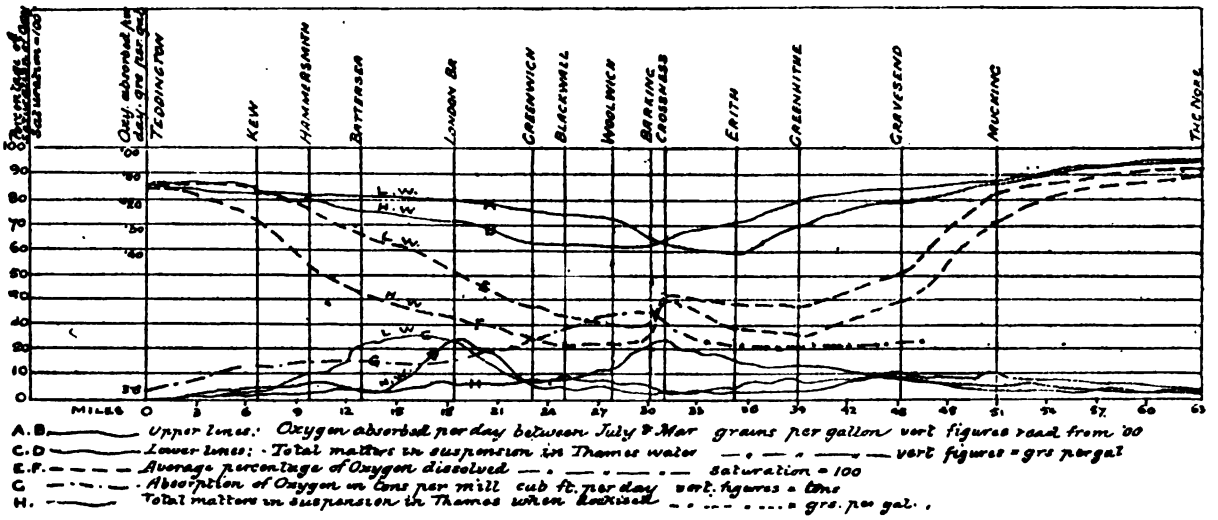
Teddington
Kew
Hammersmith
Battersea
London Br
Greenwich
Blackwall
Woolwich
Barking Creek
Erith
Greenhithe
Gravesend
Nucking
The Nore
Miles
A.B. Upper lines: Oxygen absorbed per day between July & Mar grains per gallon vert figures read from 100
C.D. Lower lines: Total matter in suspension in Thames water vert figures = grs per gal
E.F. Average percentage of Oxygen dissolved saturation = 100
G. Absorption of Oxygen in tons per mill cub ft. per day vert. figures = tons
H. Total matter in suspension in Thames when analysed = grs. per gal.

Fig. 35.

Diagram shewing states of Oxygenation and Impurity in the Tidal Thames from Teddington to The Nore.

already referred to must be put in force, the presence of fish life being the best evidence of the improved condition of the waters.

Fresh *v.* Sea Water.

A fundamental point for consideration in connection with the suggestion to form a Barrage at Gravesend, and thus create a vast fresh-water lake, is the comparative value of fresh and mixed sea waters in regard to self-purification. The first consideration in this connection which presents itself is the fact that fresh water will hold in solution a larger quantity of dissolved oxygen than sea or brackish water, and it therefore becomes necessary to ascertain beyond a shadow of a doubt what this variable factor represents in this particular case. It is commonly asserted that a soft water will facilitate the disposal of a sewage to a greater extent than will a hard water. If this is the case, how much more beneficial must the action of a clean upland river water be in regard to its action on the effluent of the London sewage than that of the brackish water into which it is now discharged? In this connection the Committee on the Charles River Dam, Massachusetts, reported that:—"Fresh water, gallon for gallon, disposes in a normal manner of more sewage than salt water; the tendency of salt water is rapidly to precipitate sewage in sludge at the bottom. For the proper disposition of sewage in water it is essential that the water be well supplied with

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oxygen. This is accomplished by the contact of its surface with the air, and this surface water is carried down by the action of the waves or currents, and especially by the vertical movement caused by changes of temperature. Bodies of fresh, nearly still water are well oxygenated to a depth of 25 feet or more in ordinary summer weather, and to much greater depths with the autumn cold. Letting in salt water under the fresh interferes with the vertical circulation necessary for oxygenation, and the salt water under the fresh soon loses its oxygen if any waste material is admitted into it. Changing a fresh-water basin into a salt from time to time interferes with the bacterial, animal and vegetable growths, which effectively aid in taking care of and digesting sewage. A comparatively still body of fresh water with animal and plant growth will dispose of a considerable amount of sewage admitted from time to time, and will tend to purify itself, even if no more fresh water is added. Such a body of fresh water will dispose of more sewage if comparatively still than if in motion." (*See* Section XII.) This is fully confirmed by the very recent paper by Messrs. Purvis and Coleman, summarised in the *Times*. (*See* p. 67.) These very important conclusions are only in accordance with general opinion, but doubtless it would be advisable to test the question in regard to the particular *locus* in a case of so much importance as the Thames.

Natural Purification: Oxygenation.

These considerations naturally lead to a review of the process of natural purification and the sufficiency of the upland water to deal with the problem presented by the London sewage. As already indicated, there can be little doubt as to the probable necessity for putting the London Sewage Works on modern lines by the practically costless addition of the requisite plant. If this were done, then we have the matter very much simplified, as we know that we might rely upon an upland water containing at least 70 per cent. of its total possible available oxygen. One gallon of water in this condition would have dissolved in it, say, 0·42 grain of oxygen available for the final purification of the sewage matters. Experimental data obtained with the one-acre filter bed at the Northern Outfall Works, at Barking Creek, shows that an effluent might be relied upon which would not require more than an average of, say, 0·7 grain of oxygen per gallon for its complete purification in every sense; so that if the volume of water coming over Teddington Weir was only twice the volume of the London sewage, more oxygen would be available from this source alone than would be required. But this does not end the story of the oxygen available for this purpose. It has been shown in my work on "The Purification of Sewage and Water"* (*see* p. 118) that the river from Teddington to Gravesend absorbs in its present condition daily no less than over 2,000 *tons of oxygen*, whereas the actual quantity which would be required by the above-mentioned filtrate would not be more than about 7 *tons*. Therefore, it is perfectly clear that the natural resources are enormously in excess of those which would be actually required to meet every circumstance of the case, and there could be no possibility of not merely nuisance, but even the very appearance of dirty water; whilst fish would be able to live in all parts of the stream, and the Thames might indeed become a clean fishing river-lake.

* "The Purification of Sewage and Water," by W. J. Dibdin.

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The following is from my paper on "Recent Improvements in Methods for the Bacterial Purification of Sewage"*:—

Aërobic *v.* Anaërobic Action.

This essential point is most interesting as bearing upon the contention that sewage *must* undergo preliminary *anaërobic* action—*i.e.*, bacterial action in the *absence* of air—before it can be finally purified by the *aërobic* action—*i.e.*, bacterial action in the *presence* of air. In order to show the fallacy of such a contention, the history of the purification of the Thames may be cited (*As above.*)

The sewage hitherto discharging into the river direct was intercepted and conveyed to new outfalls at Barking Creek and Crossness, about 12 and 14 miles respectively below London Bridge. At these points the sewage was stored until the time of high water, when it was discharged in about two hours during the first portion of the falling tide. The effect was marked. The whole of the sewage of London was thus disposed of year after year for over ten years without the slightest sign of anaërobic action. There being a sufficiency of oxygen dissolved in the water for its complete destruction, the natural aërobic agencies did their work without nuisance of any kind. After some ten years it became evident, in consequence of the increased quantities of sewage brought to the outfalls by the extension of the main drainage system and the growth of London, that the capacity of the storage reservoirs was too limited, and the sewage had to be discharged over longer and longer periods until the discharge was continuous at all times of the tide, with the result that accumulations took place at low water when there was an insufficient quantity of aërated water in the river, and putrefaction and nuisance followed in due course. This was remedied by the chemical precipitation of the grosser solid matters and their removal to sea, when the aërobic influences in the river were again able to exert their beneficent action, whilst the effect of depositing some 40 million tons of sludge in a sufficient quantity of aërated sea water in the Barrow Deep in the estuary of the Thames has been to dispose of it without the slightest sign of anaërobic action either at or about the point of discharge.

This experience on such an enormous scale clearly indicates the fallacy of the theory of necessary anaërobic action, a point which is more fully discussed later on. Hence we may safely turn our attention to the most efficient and economical method of purification on wholly aërobic lines as being not only the most wholesome and sweet, but efficient method.

Before proceeding to the consideration of the means available for effecting aërobic bacterial action, it will be advisable to consider two points which have been little understood, viz.: first, the action of water in absorbing oxygen from the atmosphere, and thereby filling the function of a "carrier" of that gas for the service of the organisms existing in the water; and, second, the action of so-called filtration.

Dissolved Oxygen in Water.

The rate at which water will re-absorb oxygen from the atmosphere is necessarily a measure of the degree of rapidity with which aërobic bacteria can multiply and work, and beyond that point it will be useless to expect results without incurring the risk of putrefaction by the agency of the anaërobic organisms. In the course of a series of experiments instituted some years back in connection with the work of purifying the River Thames, I ascertained that still water, containing no oxygen dissolved therein, will absorb in one hour 10 per cent. of the total possible quantity which it can take at ordinary temperatures and pressures, the total quantity being equal to 2·0 cubic inches per gallon under normal conditions. In two hours water will take up 20 per cent. In three hours this quantity will be increased to 26 per cent; in four hours to 32 per cent.; in

* "Recent Improvements in Methods for the Bacterial Purification of Sewage," by W. J. Dibdin.

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five hours to 36 per cent.; in six hours to 40 per cent.; in seven hours to 43 per cent.; and so on, until ten hours are required for it to absorb only one-half its total quantity, or 50 per cent. of the 1·8 cubic inches per gallon. As showing the practical bearing of these results upon the water of the River Thames, we may consider their effect on the tidal portion of the river from Teddington to the Nore. The following table shows the average percentage quantity of oxygen dissolved in the water at 15 different points at and between these places from July, 1893, to March, 1894, as determined by daily analyses at high and low tides at each place during that period:—

Average percentage quantity of oxygen dissolved in the water of the River Thames from Teddington to the Nore:—

(Saturation = 100 per cent. = 2·0 cubic inch per gallon.)

Locality.	High Water.	Low Water.
Teddington (above lock)	85·0	
Kew	70·3	85·5
Hammersmith	55·7	78·8
Battersea	42·6	67·6
London Bridge	34·5	51·8
Greenwich	24·6	37·4
Blackwall	22·5	34·3
Woolwich	22·2	30·8
Barking Creek	24·2	30·8
Crossness	43·0	41·6
Erith	39·4	29·1
Greenhithe	38·4	25·1
Gravesend	50·7	39·5
The Mucking	83·6	72·0
The Nore	90·1	89·1

From this table it will be seen that the average aëration at high and low water, between Teddington and Chiswick, is a trifle under 80 per cent. of the total possible quantity. This rapidly decreases, until at Woolwich it is only about 26 per cent., when it rises again until it is 90 per cent. at the Nore. In other words, the water as it flows over Teddington Weir is well aërated, and is able to deal with all polluting matters contained in it without suffering any material reduction in aëration—*i.e.*, the rate of absorption from the atmosphere (actual aëration being 85 per cent.) is equal to the rate of consumption by the microbes feeding on the organic matter. Further down the river this process abstracts more oxygen than can be supplied at the former slow rate at the higher degree of aëration, and accordingly the degree of aëration falls, which fall is accompanied by a corresponding increase in the rate of absorption from the atmosphere as shown by the experiments above quoted. When the rate is again equal to the necessities of the increased number of organisms feeding on the larger quantity of organic impurities, the balance is once more established, and the aëration remains constant at the lower rate.

From these observations it is evident that at Teddington, where the degree of aëration is 80 per cent., the rate of absorption of atmospheric oxygen will be 3·6 tons per 100 million cubic feet of water per day, and as the sectional volume of the river between that point and Chiswick at ***high*** water may be taken at about 250 million cubic feet, it follows that this reach of water

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will absorb 9 tons of oxygen in 24 hours, or 4½ tons on the assumption that the mean water capacity is one-half of that at high water. In like manner each section of the river may be tabulated as follows :—

Section.	Rate of absorption. Tons per 100 million cubic feet per day.	Tons of oxygen dissolved by the water in section per 24 hours.
Teddington to Chiswick	3·6 ..	4½
Chiswick to St. Paul's Pier	12·7 ..	43
St. Paul's Pier to Deptford	21·4 ..	69
Deptford to Woolwich	43·8 ..	240½
Woolwich to Barking Creek	43·8 ..	105
Barking Creek to Crossness	29·2 ..	131
Crossness to Erith	21·9 ..	126½
Erith to Gravesend	21·9 ..	716
Gravesend to Southend	5·5 ..	949
Total	.. ..	2384½

These considerations show the enormous forces at work in purifying our streams and rivers, and constitute the real secret of Nature's method in effecting the destruction of effete matters wherever they may be. A few years ago it was denied that rivers had the power of purifying themselves. At that time, however, the above facts had not been brought to light, nor had the equally important fact of the action of myriads of bacteria in utilising the oxygen so absorbed been realized, nor the bearing of these factors upon the complex problem of sewage purification been even so much as dreamed of.

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TRADE OF THE PORT OF LONDON.

In the introductory Chapter (Section I.) the general figures and conditions prevailing as to trade and its fluctuations and changes have been outlined; but it may be desirable to preface the following statements and studies by a few of the important figures relating to the past and present statistics of trade, from which can be gathered a clear idea of the tendencies of present trade and the probabilities as to its future. This can readily be done without overloading the mind with detailed figures of particular imports or exports. Matters of detail as to some individual branches of trade will be dealt with separately in the following pages.

Considering first the past and present states of the trade of the Port: these are summarised concisely in the following Table I, and a comparison made between the trade and population from which certain very definite conclusions can be adduced, bearing on the future prospects of trade and its tendencies, which will enable us to consider the provisions necessary for dealing with them in the future.

In the following Table I, the figures have been compiled from various returns submitted by official witnesses before the Port of London Commission and are substantially correct, but some reservations were pointed out due to differences prevailing at certain periods in the mode of tabulating statistics, which, however, do not materially affect the results.

TABLE No. I.

COMPARATIVE TABLE OF THE TRADE OF THE PORT OF LONDON FROM 1860 TO 1906.

(Extracted from the Report and Evidence of the Port of London Commission, 1902.)

Year.	Population of Greater London.	Value of Imports.	Value of Exports.	Tonnage of Shipping Entering.	Proportion of		Proportion of Shipping that Discharged in the		Entrepôt Trade.
					Steamships.	Sailing Ships.	Docks.	River.	
		£	£		Tons.	Tons.	Tons.	Tons.	Tons.
1853	—	—	Home produce only.	5,721,937	—	—	—	—	—
	1861						1865		
1860	3,222,720	—	30,837,688	6,111,643	1,001,309	2,153,252	2,878,235	3,233,408	—
	1871	1872	1872						
			Home produce only.						
1870	3,885,641	124,174,141	53,222,779	6,881,135	1,898,393	951,479	3,297,248	3,583,887	—
	1881	1882	1882						
1880	4,776,661	142,507,974	98,470,326	10,454,171	6,720,732	3,733,439	4,449,611	6,004,560	—
	1891	1892							1896
1890	5,663,806	144,273,415	89,012,433	13,141,455	10,456,651	2,684,804	5,394,195	7,747,260	4,105,591
	1896								
1899	6,124,853	164,105,695	88,178,000	15,388,228	14,180,272	1,207,956	6,646,111	8,742,117	3,342,757
1903	—	—	—	16,430,642	—	—	7,954,887	8,842,147	—
1906	—	199,407,311	115,353,593	17,596,315	—	—	8,114,780	9,481,535	—

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It is unfortunate that in reference to the entrepôt trade separate statistics are only available for the years from 1890. The witnesses, however, were unanimous in stating that up to about 1870 this trade had been increasing, but that since that date it had declined considerably owing to foreign ports competing and to the arrival of goods in London by rail from other ports.

COMPARISON WITH GROWTH OF POPULATION.—The Table shows firstly, that the growth of the trade has been proportionate with the growth of the population, showing a steady growth of imports but a slight falling off in exports.

It has been pointed out on p. 59 that the Port is a distributing centre for a large area outside London, which, owing to the growth of railway facilities, is probably an increasing part of its trade, but there are no means of estimating this. Further, that from the same cause and the competition of the other ports of the kingdom, there is no doubt that London is being supplied with a yearly increasing tonnage of goods that do not enter the river.

THE ENTREPÔT OR TRANSHIPMENT TRADE consists of cargoes brought into the Port and transhipped into vessels bound abroad, without landing, and therefore paying no dues. It also includes goods sent into London from other ports by rail and shipped abroad. This business is distinctly declining, the falling off being an inevitable one, due to the great increase in harbour and shipping facilities rapidly being introduced into foreign ports which are thus able to receive their own cargoes direct.

IMPORTS AND EXPORTS.—The imports show a steady growth, which is undoubtedly due to the parallel steady demand which follows from a steadily increasing population and is evidently bound to continue to grow with it.

But the exports do not follow on the same basis; their decline, as shown by the Table, has nothing to do with the general export trade of the country, which, on the contrary, has steadily increased from year to year.

The decline is due to increased facilities for exporting from the manufacturing centres by other ports, to cheaper carriage, and lower dues at other ports, and to delays in shipments in the Port of London which, with the growth of trade, have undoubtedly increased, until, in fact, a Royal Commission became necessary to enquire into its causes.

STEAM *v.* SAILING VESSELS.—The most important change exhibited by the Table is in the growth of steamships and decline in sailing vessels, both of a very marked character. The subject was thoroughly discussed before the Port of London Commission and shows that steam is rapidly ousting the sailing vessel, mainly because of its greater speed and economy. All witnesses were agreed that this change of power will continue to grow with even greater ratio in future.

DOCKS *v.* RIVER BERTHS.—The next two columns show the proportion of the shipping entering the Port which discharged in the docks and in the river. In the river the vessels either moor in the stream or lay alongside a wharf, jetty or stage. Very few wharves are long enough or have water deep enough to take vessels of any size or draught, and as these dimensions are rapidly increasing, an increase in the number of those that moor in the stream is to be noted and expected.

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The wharves have increased in number and appliances, extending further down river, but there has been no increase in the dock accommodation since the construction of the Tilbury Docks.

The figures show that the proportion of shipping discharging in the river is an increasing one, and the evidence before the Port of London Commission showed clearly that this is due to (*a*) Dock charges; (*b*) Delays in dock; (*c*) Greater facilities for barging in the river; (*d*) Lower wharfage charges.

Dock Charges.—Many complaints were made as to these, and unfavourable comparisons drawn between those of the Port of London and other British and foreign ports, particularly the charges for landing and quayage, sorting and warehousing. Some of the evidence on this point is given on p. 164.

Delays in Dock.—That these are becoming more serious year by year is manifest from the evidence given, and from the fact that a great increase in number and tonnage of barges frequenting the docks hampers the despatch of goods and delays discharging and loading. Numerous complaints were made of these delays, see pp. 164-5. The docks are also sluggish in their methods, employ antiquated machinery, and a great deal of unnecessary red tape, which greatly retard the transaction of business.

Greater facilities for Barging from and to Ships in the River.—In dock the barges (see p. 137) are detained for many days, have to get their cargoes when they can, the quay space being generally occupied and the goods sorted there; a vast amount of time is lost in getting the goods. In the river this sort of delay is almost unknown. Barges can get alongside at any time (unless there is one already in the berth) and lose no time in getting into and out of dock. In this way they can work at lower rates.

Wharf Charges.—These were estimated at 10 per cent. less than those of the docks, and there is no standing entry-due of 1s. 6d. per ton to pay, which necessarily gives a considerable margin of saving to the wharf-discharged ships.

Probable Future Tendency of the Trade.—The Table indicates clearly—and the evidence of witnesses on the Port of London Commission confirms—the directions in which the future trade may be expected to develop, and the changes and requirements which have to be met.

The increase in size and draught of vessels will require a corresponding increase in depth of water in the river and docks and entrances, with ample width of river for safe navigation, or else deep water docks or wharves in the lower part of the river or estuary.

The requirements of modern shipping call also for much greater dispatch in loading and discharging—more rapid movement of barges or of land carriage, more modern machinery for handling cargoes, cheaper supervision and establishment charges, less circumlocution and official red tape methods. Some means must be devised for preventing tidal and fog delays at Gravesend. Reduction of pilotage and abolition of compulsory pilotage and licensed labour, better railway facilities to the riverside, besides many more improvements.

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It is evident that there is an indirect competition between the shipping and the railways, in which the latter are gaining ground by giving facilities for cargoes landed at other ports, many of which would enter the Port of London if the requirements of modern shipping were better provided for. Such provisions would help also the trade to the Midlands using London as the port of entry.

Changes in the growth or decline of particular articles of consumption cannot be anticipated nor do they affect the total import or export trade. There are, however, certain special goods, such as green fruits, fish, wood, groceries, &c., that require accommodation of a special kind that cannot be shifted about.

Warehousing alongside is, again, a diminishing business, an increasing proportion of the goods going from ship to merchants' warehouses, so that less provision for warehousing at the dock or wharf—unless far down the river—is likely to be in demand.

With a change of administration many changes are likely to be instituted in the levying of dues, customs supervision (which causes much delay), weighing, taring, metering, labour and licensing, mooring, policing and so on, which, while facilitating business, will reduce expenses.

It is also probable that motor barges will be introduced and displace the present slow tide-drifting barges, and also that towage will become general throughout the river to—so far as possible—make barging independent of tides. It will follow from this that the practice of discharging in the river—if there is depth enough—will increase the barging business, using the barges, as now, as intermediaries between the ships and the warehouses or landing quays, which makes it desirable, in fact essential, that barging shall be much more rapid than now and not subject to delays. There should be as much freedom for barges in the river as for vans in the streets at all hours, but it is manifest that this can only come about by the introduction, generally, of power instead of the present tide-drifting system.

There is also room for great improvements in the mechanical appliances for handling cargo throughout the Port, both on the ships and quays. Much has been done, but much more is possible.

Comparative Growth of Other Ports.—A good deal has been said and written as to the decline of London as a port and the rise of other competing ports, some of which is true, but much of it is calculated to convey wrong impressions.

Whatever may be the growth of other ports, London is the largest market in the world and, as long as water carriage is cheaper than land carriage, is bound to have a port in which the bulk of its supplies will be delivered, and the growth of which will necessarily follow that of the population.

Unless vessels can discharge at out ports at a cost which, added to railway rates, is less than the charges in the river, the Port of London can easily maintain its own, provided that the port facilities keep pace with the traffic.

The following tables show in round figures the comparative growth of other ports —British and foreign—some of which may be considered as in competition more or less with London.

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COMPARATIVE TABLES OF THE TRADE OF BRITISH AND CONTINENTAL OUT-PORTS, FROM THE EVIDENCE OF THE PORT OF LONDON COMMISSION, &c.

TABLE No. 2.

NUMBER AND TONNAGE OF VESSELS IN FOREIGN TRADE, WITH CARGOES AND IN BALLAST ENTERING AND CLEARING FROM SOME OF THE CHIEF PORTS IN THE UNITED KINGDOM, SHOWING THE INCREASE OF SHIPPING IN 1898 IN EACH PORT OVER THAT OF 1890.

(Compiled from Figures supplied by the Board of Trade.)

Name of Port.	1890.		1891.		1892.		1893.		1894.	
	Vssls.	Tons.	Vssls.	Tons.	Vssls.	Tons.	Vssls.	Tons.	Vssls.	Tons.
Bristol	1,036	778,151	1,062	830,282	1,099	913,238	1,102	928,274	1,240	1,102,536
Cardiff	10,526	8,815,210	10,987	9,386,335	11,003	9,779,179	10,221	9,408,044	10,723	10,478,391
Hull	6,108	3,653,134	6,213	3,813,676	6,343	3,801,180	5,477	3,415,330	6,173	3,933,123
Liverpool ..	8,676	10,941,801	8,246	11,087,908	7,981	11,119,976	7,191	9,839,801	7,279	10,489,578
London	18,531	13,480,767	17,866	13,425,517	18,180	13,916,459	17,376	13,418,056	18,042	14,433,580
Middlesbrough	2,534	1,457,529	2,254	1,349,233	2,025	1,193,869	2,496	1,749,532	2,704	1,949,142
Southampton	3,582	1,701,485	3,541	1,751,576	3,555	1,735,535	3,759	2,130,753	4,187	2,323,516
Sunderland ..	3,034	1,682,125	2,905	1,716,318	2,639	1,561,047	3,143	1,979,733	3,223	2,084,519
Swansea ..	3,356	1,423,859	3,166	1,369,041	3,273	1,422,488	3,087	1,320,144	2,943	1,342,710
Tyne Ports ..	14,199	8,411,314	14,411	8,876,494	12,189	7,496,225	12,555	8,028,392	13,362	8,655,115
Glasgow.. ..	2,556	2,819,362	2,303	1,657,057	2,548	2,940,905	2,200	2,748,599	2,143	2,760,274
Grangemouth	2,405	1,031,922	2,678	1,188,882	2,970	1,340,928	2,835	1,269,767	2,346	1,071,454
Leith	2,741	1,333,064	2,927	1,445,580	2,950	1,544,337	2,880	1,569,432	2,871	1,571,498
Belfast	486	330,179	477	329,227	634	483,184	551	442,969	585	493,429
Dublin	489	327,765	459	307,948	486	373,559	460	335,791	486	369,956

TABLE No. 2—*continued.*

Name of Port.	1895.		1896.		1897.		1898.		Increase in Tonnage in 1898 over 1890.
	Vssls.	Tons.	Vssls.	Tons.	Vessels.	Tons.	Vessels	Tons.	
Bristol	1,102	948,867	1,241	1,108,782	1,166	1,091,316	1,156	1,173,859	50·8
Cardiff	10,547	10,201,125	10,651	10,905,144	11,162	11,990,709	8,306	8,788,105	−·4
Hull	5,602	3,763,339	5,878	4,011,909	6,093	4,140,982	6,458	4,627,480	26·6
Liverpool ..	6,884	10,481,540	6,895	10,883,024	6,928	11,261,051	7,149	12,168,802	11·2
London	17,725	14,546,001	19,124	15,582,195	19,105	15,797,659	19,704	16,596,202	23·1
Middlesbrough	2,588	1,829,044	2,828	2,016,807	2,607	1,996,083	2,268	1,783,053	22·3
Southampton	4,152	2,748,924	4,348	2,998,254	4,260	3,008,209	4,362	2,923,611	71·8
Sunderland ..	2,726	1,732,948	3,842	1,801,190	2,977	1,943,967	3,022	1,961,740	16·6
Swansea ..	2,971	1,512,069	2,921	1,491,717	3,143	1,600,869	3,598	1,922,071	34·9
Tyne Ports ..	12,055	8,115,272	12,639	8,461,572	*10,179	*7,382,737	*10,573	*8,209,512	−2·4
					3,307	1,986,511	3,634	2,401,103	26·1
Glasgow.. ..	2,505	3,096,276	2,509	3,191,707	2,576	3,421,386	2,766	3,684,443	30·5
Grangemouth	2,730	1,331,138	2,879	1,395,347	2,844	1,483,116	2,765	1,482,279	43·6
Leith	2,895	1,638,099	3,109	1,792,682	3,203	1,831,245	3,220	1,977,117	48·3
Belfast	566	486,550	580	526,047	647	685,400	560	608,631	84·3
Dublin	449	346,152	436	352,167	434	379,924	377	311,191	−5·1
Total entering and clearing from the Ports in this Table in 1898 ..								70,619,199	
Total entering and clearing from all Ports in the United Kingdom in 1898								99,963,966	

* Blythe, which was formerly included in the Tyne Ports, was made a separate port in 1897, and the figures are added separately for 1897 and 1898.

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TABLE No. 3.

FOREIGN PORTS. TONNAGE OF SHIPPING ENTERED.

Year.	Antwerp.	Hamburg.	Bremer-haven.	Bremen.	Amster-dam.	Rotter-dam.	Havre.	Dunkirk.
		1853.						
1850	350,000	560,000	120,000	200,000	180,000	376,000	—	150,000
		1865.						
1860	500,000	1,330,000	325,000	450,000	420,000	593,000	800,000	280,000
		1875.						
1870	1,400,000	2,120,000	500,000	550,000	400,000	1,026,000	1,200,000	500,000
		1885.						
1880	2,700,000	3,700,000	1,000,000	1,200,000	730,000	1,682,000	1,950,000	800,000
		1895.						
1890	4,600,000	6,254,000	1,280,000	1,800,000	870,000	2,918,000	2,100,000	1,500,000
1899	6,800,000	7,766,000	1,460,000	2,400,000	1,800,000	6,326,000	2,200,000	1,650,000
1904	6,652,440	8,705,164	1,464,381	1,125,156	—	6,879,433	—	—

TABLE 2.—The general conclusion to be drawn from this table is that British ports have nearly all progressed in an even ratio, with only such fluctuations as may be accounted for by good or bad years, or changes of local industries, and, in themselves, give no indication of any direct competition with London, with the possible exceptions of Liverpool and Southampton, in both of which, however, the increases are largely due to the growth of the great steamship lines which London never accommodated, the western and southern ports being much more convenient for their traffic than London.

TABLE 3.—Shows that much of the entrepôt trade which London has lost has gone to Antwerp, Hamburg and Rotterdam, and, in a less degree, to other ports. But, speaking generally, the table shows that these ports have grown in traffic in a very regular progression since 1850, which has kept pace with the growth of the Continental nations and of their external trade. There is nothing surprising or alarming in the fact that other nations are making progress parallel to our own, developing their resources and interchanging traffic with us.

We held a position of supremacy in 1850 impossible to be maintained, and should welcome the progress of neighbouring nations who can trade with us and by their own industry secure the means of paying for their purchases. A poverty-stricken Europe would shut up many of our markets.

The remaining lesson to be drawn from information as to expenditure on the Ports, shewn in Table 3, is that these foreign ports have only gained their great extension of trade by great efforts in the provision of modern appliances and methods, and London must keep pace, or better still, keep in front in these respects to maintain its fair share of trade.

A DEEP WATER PORT NECESSARY.—Table 4 is introduced here to emphasise—by statistics of the progressive growth of the shipping—the need for increasing the depth of water in the tidal river and estuary, which, in fact, is a subject that all are agreed upon and was much insisted upon by most of the witnesses on the Port of London Commission.

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TABLE No. 4.

SHOWING THE INCREASE IN THE SIZE OF SHIPS.

(Compiled by the Secretary of Lloyd's Register of British and Foreign Shipping.)

VESSELS REGISTERED UNDER THE MERCHANT SHIPPING ACTS IN THE UNITED KINGDOM.

NET TONNAGE.	DECEMBER 31ST, 1871.		DECEMBER 31ST, 1898.	
	Number.	Tons.	Number.	Tons.
Under 2,000 tons—				
Sail	21,804	4,274,639	11,138	1,893,080
Steam	3,325	1,195,915	7,829	3,925,111
Total	25,129	5,470,554	18,967	5,818,191
Over 2,000 tons—				
Sail	13	30,473	203	473,459
Steam	46	121,633	977	2,683,450
Total	59	152,106	1,180	3,156,909
Total—				
Sail	21,817	4,305,112	11,341	2,366,539
Steam	3,371	1,317,548	8,806	6,608,561
Total	25,188	5,622,660	20,146	8,975,100

The table shows graphically and emphatically that the growth of tonnage of ocean-going ships has been very rapid, and the resources of every port have been taxed and expanded to accommodate them.

The question naturally arises: Have we reached the limit of the dimensions of ocean-going ships or is the increase likely to proceed at a similar ratio in the future? If not, where is the limit?

There is a general consensus of opinion that the limiting draught—if not the general dimensions of ocean-going ships—has almost been reached; not because there is any insurmountable difficulty in building larger vessels or in handling them, but because a draught of much more than 30 feet will limit the ports approachable by such vessels to such a small number as to put them out of competition. The difficulty also of obtaining freights in large parcels for very large vessels is increasing rather than diminishing, and there is also a limit to the economical working of large vessels which seems to have been reached. The largest are almost entirely engaged in passenger traffic and mail service and not in freights.

The opinions, therefore, of shipping experts and of merchants is that no further increase in draught is possible, and, as this practically limits size and tonnage, no further notable increase is practicable unless some entirely novel and drastic change or new invention in ocean vessels comes into use.

There are now 80 vessels of over 7,000 tons gross afloat, of which 40 are over 10,000 tons, but most of those of British origin are owned in Liverpool and Glasgow, very few of them in London, which indicates that the Port of London is not considered practicable for very large vessels owing to want of depth of water and to tidal difficulties of navigation.

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Dues, Charges, and Expenses of the Port of London.

In Section XXII., the total sums drawn from the trade of the Port in the form of dues, charges, dock and wharf charges, and other expenses are set out as part of the financial aspect of the Port Administration.

In connection with and from the point of view of the traders, merchants, shippers, and shipowners and other kindred trades, it is necessary to review briefly the incidence of these dues and charges in the Port, comparing them with those levied in other ports in the United Kingdom and abroad.

Charges very materially influence trade, in some sections of which comparatively small increases or decreases operate to greatly depress or expand them. This is particularly the case with low-priced goods in bulk, and when competition is keen in the markets, small differences in cost are often sufficient to transfer trade from one direction to another. Hence the keen competition of tariffs, rates and charges.

The complaints of merchants and shippers, so far as they related to charges and dues, apart from delays, &c., were chiefly directed against the dock charges, pilotage, and demurrages (see p. 164). Some differences of opinion existed as to the general comparison of port charges with those of other ports, as apart from dock dues, delays, &c.; but the tables elaborately prepared by the Dock Trust Sub-Committee of the Chamber of Commerce, and published in the Appendix to the Port of London Commission show conclusively that—as stated in the Report (App., p. 85):—

> An investigation of these tables shows that, for the class of traders who import goods on their own account, or who buy ex-ship and take the goods away in their own barges to their own factories or warehouses, London is practically a free port; but for the much larger class of traders —the importing merchants who bring their goods to the London market for sale as a centre for distribution—it is, as regards the docks, the most expensive port in the United Kingdom.

To the foregoing may usefully be added a table prepared by Mr. (now, Sir) A. L. Jones (App. Port of London Commission, p. 376 App.) showing the comparative charges on a cargo vessel of 3,388 tons gross in London and at various Continental ports.

TABLE No. 5.

Comparative Port Charges and Time Occupied in Discharging a Modern Cargo Steamer of 3,388 Tons Gross at various Ports in England and on the Continent. (Mr. A. L. Jones.)

	Avonmouth.	Liverpool.	Hamburg.	Rotterdam.	Antwerp.	Bremerhaven.	London.
Number of days ..	3	3	7	5	6	4	6
Harbour and River dues	—	—	—	30 0 0	—	—	7 17 3
Dock and Quay dues..	146 9 4	146 9 4	183 8 11	—	55 0 0	109 0 0	125 17 0
Pilotage, Tug hire, and Boatmen	18 10 0	25 10 0	29 0 0	36 0 0	44 10 0	27 0 0	36 13 9
Totals	164 19 4	171 19 4	212 8 11	66 0 0	99 10 0	136 0 0	170 8 0
Stevedoring.							
Discharging 4,500 tons	243 15 0	137 10 0	140 18 7	100 0 0	114 11 8	132 0 0	182 1 8
Overtime	—	42 0 0	24 0 0	15 0 0	5 0 0	18 0 0	34 6 0
Tallying	—	—	19 12 0	35 0 0	21 0 0	30 0 0	47 5 4
Crane and Winch hire	—	—	—	—	20 0 0	—	24 18 9
Totals	243 15 0	179 10 0	184 10 7	150 0 0	160 11 8	180 0 0	288 11 9
General Totals ..	408 14 4	351 9 4	396 19 6	216 0 0	260 1 8	316 0 0	458 19 9

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Here again, London figures badly, being about 35 per cent. higher in total charges than the average of the other ports. But the excess is not in the port dues, which are less in London than most Continental ports, but in the dock and wharf charges, labour, barging and other expenses, not being port dues, in which London is dearer than most other ports.

The Port dues are the following :—

THAMES CONSERVANCY DUES :

½d. per registered ton on vessels coastwise, or from or to foreign ports, north of Ushant, with certain exemptions.

¼d. per registered ton on those trading to other ports.

TRINITY HOUSE DUES (Lighting and Buoying) :

2¼d. per registered ton on vessels trading in home waters.

2¾d. per registered ton on vessels trading outside these waters.

But the payments are limited to six voyages per annum.

The Dock dues are the following :—

LONDON AND INDIA DOCK CO. :

Dock charges, 1s. 6d. per registered ton, barges and craft exempt.

Landing charges, from 9d. to 60s. per ton.

Extra charges for all other services.

SURREY COMMERCIAL DOCK CO. AND MILLWALL DOCK CO. :

Docking charge, 1s. per registered ton, barges and craft exempt.

Landing charges, grain, 1s. 9d. to 2s. per ton ; wood, 7s. per standard, or from 9s. to 11s. per load.

Extra charges for all other services.

WHARFINGERS' CHARGES.—These vary considerably at different wharves and with different classes of goods, but there is no charge corresponding to the dock companies' docking charges of 1s. and 1s. 6d. per registered ton.

Mr. J. J. Rogers stated that (Port of London Report, p. 61) a careful comparison of the wharfingers' charges showed that they averaged 10 per cent. less than those of the dock companies.

VESSELS DISCHARGED IN THE STREAM escape the docking charges and only pay landing charges on such goods as they land per barge at a wharf, or dock charges if they send them into dock, but in place of the docking charge they pay a small rent for moorings. Most of the moorings belong to the Thames Conservancy Board, but are farmed out to private owners ; the remainder are privately owned and the charges range from 10s. to 25s. for each vessel.

The Report of the Royal Commission on the Port of London bristles with complaints as to all these charges and the way in which they are levied. Not all of these complaints are justified, of course, but the tenor of them may be estimated from the extracts given on pp. 164-5, which might be extensively multiplied.

PILOTAGE.—The charges for pilotage are undoubtedly high, but chiefly because both a sea pilot and a river pilot have to be engaged and a double fee incurred, whereas

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in most Continental ports only one pilot is required. The total sum paid annually amounts to £146,096.

The pilotage rates for London are given in Table 6.

TABLE No. 6.

COMPARATIVE STATEMENT OF THE PILOTAGE RATES FOR STEAM VESSELS DRAWING 8 FEET, 18 FEET, AND 28 FEET OF WATER IN THE PORT OF LONDON, THE DISTANCE PILOTED AND THE RATE PER MILE.

Distance of Pilotage.	INTO PORT. Rate for Steam Vessels drawing			Average Rate per Mile.	REMARKS.
	8 feet.	18 feet.	28 feet.	Inwards.	
Miles.	£ s. d.	£ s. d.	£ s. d.	s. d.	
87 Sea	3 12 0	9 1 6	20 11 9	2 6½	
23 River	0 18 9	3 6 0	9 10 6	3 11½	
110	4 10 9	12 7 6	30 2 3	2 10	
	OUT OF PORT.			Outwards.	
87 Sea	3 12 0	9 1 6	20 11 9	2 6½	
23 River	0 18 9	3 6 0	9 10 6	3 11½	
110	4 10 9	12 7 6	30 2 3	2 10	

WHO PAYS THE DUES AND CHARGES?—Unquestionably, as clearly shown by Mr. Gomme for the London County Council (Port of London Commission, p. 164), all these are paid by the consumer in the price he is charged for his goods, and he has no voice whatever—except through Parliament—in the assessment or collection of the dues and charges.

But, wherever charges unduly bear on particular classes of goods and thus the prices become enhanced, every person contributing to the distribution of the goods is liable to be affected by restriction of trade, in which comparatively small additions or reductions often seriously retard the business done: for an article sold, say, at 10s., is only purchasable by perhaps 1,000 persons, whereas, if its selling price can be reduced by cheaper delivery expenses to, say, 8s., the purchasers will probably be multiplied to 5,000 or more, and therefore the merchants, brokers, shippers, shipowners, wharfingers and everyone engaged in handling it be correspondingly benefited by increased business.

It is, perhaps, difficult to specify and locate the particular hardships introduced by the different overcharges, where everyone must be affected more or less; but an examination of the evidence given by these different trades shows that while all the dues and charges—although paid by the shipowner or the merchant—affect everyone who intervenes between the consignor and the consumer, certain of the charges operate hardly on particular trades.

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It must be noted, too, that none of the persons who handle the goods between the consignor and the consumer have any interest in the price they fetch ; their interest is concentrated in the tax they levy on them, and the price only interests them in so far as it restricts or facilitates trade.

Neither the consignor nor the consumer has much, if any, power to control the charges levied in transit. They can do little more than grumble, for the port interests are practically vested monopolies that cannot be evaded.

But there is a sort of automatic balance or equilibrium of an unstable character always existing among the port trades, shifting at times as prices and traffic fluctuate, and making a rough and clumsy adjustment of expenses to the circumstances of the moment, but without system. Competition among the trades is the moving force in this adjustment, as in all trades—that of the wharves against the docks ; of one dock or wharf against another for particular classes of goods, or lines of steamers, besides the natural competition within each trade, by which prices are prevented from becoming excessive. But this does not apply to pilotage or licensed labour.

The docking charge of 1s. or 1s. 6d. per registered ton (which is equivalent to about 1s. 4d. and 2s. per ton of goods) is a tax that tells chiefly on the larger vessels which use the docks, and is avoided by those that moor in the river. The heavy landing and other charges within the docks certainly handicap the former still more severely in competition with the latter, and must tell in competing for freights.

In pilotage, again, coastwise vessels are exempt, and ships of less than 60 tons ; also ships trading to ports north of Brest, inclusive.

The river dues are very small—admittedly so ; but even these are not paid by a large proportion of the smaller vessels, all under 45 tons being exempt, as well as fishing and passenger vessels, and ships with cargo for re-exportation, and ships in ballast.

The Dock Companies and Wharves.

Their financial and other circumstances have been considered in Section XXIV. It is only necessary here to refer to them as trading companies influencing or controlling the trade of the Port.

So far as financial position is concerned, they are nearly on an equal footing. Thus, the total capital of the

Dock Companies is	£24,500,000
and of the Wharves	13,141,235

and the profit income of the

Dock Companies	£732,856
Wharves	688,824

But, besides the wharves, trading as wharfingers, there are many riverside factories and works carrying on their own businesses, and not engaging in wharfingers' business—that is, receiving and storing goods for the markets.

These factories are rapidly increasing, and will undoubtedly constitute in the future a strong independent waterside interest, holding an independent position, as it were, outside both wharf and dock ; the capital invested in their businesses

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amounts to £100,000,000, or three times that of the docks and wharves combined. They constitute by far the most important and increasing part of the trade of the Port; but as they do not compete with the wharves or docks, they have not been much heard of, and have a different interest in the question of dues and charges.

Besides any rental for foreshore rights, which they may pay to the Thames Conservancy Board, they only pay the river dues, pilotage, barging, moorings, tug hire and any labour they may require outside their own employees, and are thus to a large extent outside of the general competition of the river. Their prosperity depends on cheap water carriage and free navigation; and being producers and not mere middlemen, their presence is a source of wealth and not a tax on products, entitling them to the greatest consideration on any question of dues or charges affecting them.

Nearly one-half of the shipping and goods is dealt with by these riverside factories, to which every encouragement should be given as an important and increasing source of employment and industry.

Changes that will be effected by Dockisation of the River.

Having considered all the salient features of the existing trade of the Port of London, its progress, wants and defects, the changes that will follow the construction of a Barrage at Gravesend may now be studied, and the advantages that this drastic alteration in the conditions of trade, navigation and waterway may be fairly appreciated.

These may be considered under the following heads:—

1. Effect produced on the cost of navigation, pilotage, towage, &c.
2. Time expended in port and the question of delays.
3. Reduction of dock and wharf expenses in handling cargo, overside or on quay.
4. On barge traffic and on employment of labour.
5. Effect on expenses of Harbour Board or Port Trust in management and administration of the port river dues.
6. Effect on riverside and dock extensions and future trade, riverside factories, deep-water quays, jetties or wharves.

(1.) Effect on Navigation.

This must be considered in relation to (*a*) steam ships; (*b*) sailing vessels; and (*c*) barges and craft.

(*a*). *Steamships* almost invariably steam up and down without a tug and will continue to do so, the time occupied in passing the 26 miles of river will be probably half an hour longer with no tide; but as against this must be set off several hours saved in getting into or out of dock, and absence of tide waiting at either Gravesend or London; the gain in time must be considerable, besides the reduced risk. Pilots will, in most cases, be unnecessary.

(*b*.) *Sailing Vessels* can easily sail up or down, and so save the tug now almost always employed; or, if the wind is unfavourable, still use the tug, as heretofore. For sailing they will have the entire width of the river to manœuvre in and pilots will be unnecessary.

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THE THAMES AT BLACKWALL.

[*To face p.* 133.]

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(c.) *Barges and Craft:* Probably two-thirds of these are towed now, and the other third will have to adopt towage as a rule, though for short trips rowing will be practicable. But they will never have to wait for tides, dock entrances, wind or weather, and thus will gain very largely in cost of working. (*See* page 135.)

The greatly increased safety of the navigation is a matter not to be ignored. Its money value will be seen in reduced insurance and compensations for sunk barges, vessels, damages by collision or drifting.

(2.) Time expended in Port.

The loss of time is unquestionably now the most serious drawback to the Port of London, for demurrages are very costly to owners and shippers, and keep large sums of capital useless and idle, besides increasing current expenses of handling cargoes.

Much of this loss of time will clearly be saved when the entire river and the dock entrances can be navigated at any hour day or night, or even in fog (*see* page 47), and the same freedom given to the barges and craft which load or discharge the ships. It may reasonably be expected that a time saving in every department will follow, constituting in itself a considerable average percentage of saving in expenses.

(3.) Reduction of Dock and Wharf Expenses.

The savings effected by dockisation on the dock companies' expenses in connection with their entrances, mudding, &c., are detailed on page 37. In the case of the wharves, the gain will be in always having deep water fronting them, enabling work to be carried on, and barges and vessels moored or unmoored at all hours continuously. There can be no doubt that one of the results quickly adopted will be the continuous loading or discharging of vessels day and night until finished, by day and night shifts, thus effecting at least a 50 per cent. reduction in the time in port.

Vessels can also be loaded or discharged more expeditiously when always at one level and free from tide current. This was asserted by several witnesses as one of the advantages of the docks. (Port of London Commission Report.)

(4.) The advantages to the barge traffic have been fully gone into in Section XX.

Labour is now, to a great extent, tidal, and the working hours thus limited; besides the great loss of time waiting, which either limits the men's hours or increases their rate per hour. Pleasure traffic on many reaches of the river will introduce quite a new industry, or, rather, revive an ancient one, which will give employment to thousands. The same results must follow the extension of riverside factories. Regular hours and steady employment, instead of irregular and intermittent work is a great boon to working people, which the river work certainly does not now provide.

(5.) Expenses of Harbour Board.

That is to say, the cost of administration of the Port.

In the estimates in Section XXIII. it has been assumed that the cost under the new *régime* may be taken as the same as those of the present Thames Conservancy Board. It will take over, in addition to the duties of the latter body, the lighting, moorings,

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buoys, policing and probably sanitary work, so that it may be expected to cost more than now ; but these additional duties will devolve upon it whether the river be dredged or dammed. In a tideless river, however, the work of regulating the traffic, policing, &c., will be much easier to carry out.

(6.) Effect on Riverside, Dock Extension, &c.

As the riverside for the entire length of the river to Gravesend will be available for wharves or factories, a great appreciation of value of the marginal lands will follow.

The construction and working of such factories with their wharves will augment the trade in the river. In this augmentation all river interests must necessarily benefit, directly or indirectly. Factories employ labour, labour requires supplies, roads, railways and other conveniences ; but the chief artery for traffic must necessarily be the river.

It is not likely that further dock extensions will be needed for a long period, if at all ; the present docks are by no means full. Under this proposal they will form part of the river wharfage, and can probably double their volume of business without any extension of docks.

Jetties, or deep water quays, may in places be found desirable where the depth alongside is insufficient. These can be much more cheaply constructed and operated in a non-tidal river than in a tideway however.

It is evident that trade in a dockised river will be carried on under greatly improved conditions, tending to reduce materially the expenses and losses incidental to the traffic. These savings will attract trade now alienated, improve existing trade, lessen the burdens all round, and equalise the charges, making, in all probability, the Port of London one of the cheapest instead of the dearest port in the world.

At the Fourth Conference of the Institute of Civil Engineers, June 18th-21st, 1907, Lord Pirrie, speaking on Harbour and Dock requirements as affected by the development of shipping, complained that shipbuilders had to restrict their ideas as to dimensions to suit the channels, dock entrances and graving docks in existence. Ships drawing 22 to 24 feet were delayed at Gravesend, and there were only two or three places between the Albert Dock and Gravesend where such ships could lie at anchor at all states of tide.

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THE BARGE TRAFFIC.

Barges have been, from an early period, the common means of transit of goods on the river, using the river as a highway, and occupying the place of middlemen between the ship and the dock or wharf.

As the river business is now conducted, about half the shipping—including a large proportion of the larger vessels—enters the docks, and the other half, including a large proportion of the coasters and the small vessels, either ranges alongside the wharves or stages, or discharges at moorings in the stream (*see* Table).

DISTRIBUTION OF SHIPPING ENTERING THE PORT OF LONDON.

	FOREIGN TRADE.	COASTWISE.	TOTAL.
	Tons.	Tons.	Tons.
Docks	6,319,653	1,000,000	7,319,653
River, *i.e.*, Wharves, Moorings, &c. ..	2,622,446	4,920,784	7,543,220
Queenborough	615,318	29,494	644,812
	9,557,417	5,950,278	15,507,685

The work of barging, therefore, consists in transferring from ships in dock parts of their cargoes destined for wharves or other ships, or from dock to dock—receiving from ships moored in the river their cargoes for delivery to wharves or riverside factories, or into dock, and carrying from wharf to wharf or from wharf to ship, and so on.

If it were possible for ships to go from wharf to dock in order to deliver their several consignments direct, much of the barging could be avoided. But this is impossible in most cases, besides being impracticable, owing to the size of large vessels and the difficulty of moving them about in the river. It is found cheaper and more expeditious to barge such traffic. But few ships are able to obtain entire cargoes of one kind except in the case of coal, grain, and similar goods, to be landed at one point, so that most cargoes have to be sorted, which is best done on a quay, involving double handling and delay.

It is found also that cartage from point to point on the riverside is much more costly than barging. The average cost of barging was stated by Mr. R. N. Tough, Lighterman ("Port of London Commission," p. 210), to be only 1d. per ton of rough goods per mile; 2d. per ton for more valuable goods, and coal at $\frac{5}{8}$d. per ton per mile. Cartage would cost at least 4d. per ton per mile for similar distances.

The very large volume of the barge traffic must be evident from the number of entries of barges into the docks, given on p. 57, at 213,736 per annum. The number

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of barges in active service on the river is given by the Port of London Commissio 8,000, consisting of dumb barges, sailing barges, lighters, luggers, &c. And tonnage varies from 20 to 100 tons.

On account of the strong tides it is said that larger barges cannot be used, as t are unmanageable, except by tugs. On many Continental rivers, however, v quite as strong currents, barges of 250 tons, many of them fitted with motors. common, and an effort is now being made to introduce similar motor craft into Thames, where they would be of the utmost value, if properly designed to suit conditions of the river.

But under tidal conditions barging is necessarily tidal also. That is to say, th movements are subject to tides; even when towed, they rarely tow against the ti The effect of this is to restrict the working hours to little more than half the work day.

To this must be added an enormous loss of time due to waiting for entrance the dock, for exit from the same, for a berth in the dock, either alongside a ship quay; waiting in the river for a berth alongside a moored vessel or a wharf; lying aground at low water, and other causes. The great extent and everyday occurrenc of these wasted waiting hours and days is a matter of common observation that everyon may make from the bridges. Fleets of barges may be seen every day moored in th stream, lying on the mud, waiting turn alongside shipping, waiting in fleets outsid dock entrances, &c., to such an extent that it excites no remark, being a common feature of the river.

But it follows, to a business man, that there must be something radically wrong in a system that daily and every day creates this loss of time, falling, as it inevitably does, on the cost of materials and of labour; the employment of a capital and plant greatly in excess of the work to be performed, which, in fact, if the tides were eliminated, could be performed by little more than half the number of barges now employed.

In this connection the slow speed of movement of the barges, drifting on the tide, averaging about 2½ to 3 miles per hour, is another factor in increasing the cost of barging and in reducing the work done in any given time. If the speed could be doubled a great increase in the output would result, or, as an equivalent, an equal reduction in cost of labour and interest on capital. Six miles an hour is not an outrageous speed. Tugs can accomplish even more with a tow of barges on the tide, but rarely attempt to tow against it.

It is becoming generally admitted that towage is cheaper than drifting, although there is a cash difference in favour of the drifter of about 3s. per barge, as stated by witnesses on the Port of London Commission; but where the distance is more than a mile or two, or time is of importance, towing must be the cheaper method, as well as the most expeditious, and is thus greatly on the increase.

With a tidal river, and its inevitable waiting delays, the manifest advantages of motor barges, or even towing, must necessarily be difficult to realise. Vessels under steam must be kept going to pay for their power. Oil motors, however, need not

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GREENWICH PARK.

WESTMINSTER PIER.

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do so, and seem to offer the best solution, but must be designed for very rough usage, such as falls to the lot of all machinery afloat.

. Economical barging, therefore, requires larger barges for rough goods—(small barges will still be needed for small consignments)—greater speed, great reduction of delays, and of loss of time in tide and other waiting.

If the river is dockised it would seem that all these improvements may be realised, with the loss only of the transporting power of the tides as a set-off. The value of this is merely the difference, if any, between the cost of drifting and towage. It has been seen that this is only in favour of drifting in the case of short journeys; but if towage or power barges were general, it is certain this difference would disappear in favour of the towage system. Mr. R. N. Tough stated (Port of London Commission, p. 210) that the charge for towage was 6½d. per mile per craft, which, taking 40 tons as an ordinary barge-load, is only one-sixth of a penny per ton per mile, to which, of course, must be added the cost of the lighterman in charge. But even if the towage charge is to be reckoned wholly in excess of the cost of drifting, it is so small as to be easily set off by saving in time.

Mr. R. LAMBERT stated (Port of London Report, p. 201): At the present time a very large proportion of the barges used for the transportation of merchandise are towed by tugs.

DELAYS: LOSS OF TIME.

But the delays spoken of, to which barges are subject, were complained of by all the barge-owner witnesses at the Port of London Enquiry.

Mr. R. N. TOUGH said (extracts from Report, pp. 209 and 210): (4080) We require and obtain from one penny to threepence per ton extra for dock work as against the stream.

I put in a table showing the length of time occupied by the Millwall Dock Company in discharging 33 of our barges.

The length of time entailed a loss upon the merchant of £108 5s. for demurrage on barges beyond the charge for lighterage; the delay further locked our barges up, and prevented our accepting traffic offered us, and caused customers of ours to look round and endeavour to get their traffic placed elsewhere. These 33 barges were 370 days in all discharging or waiting to discharge after getting into dock, being on an average of more than 11 days each barge.

I also put in a table showing the length of time occurring between vessels' arrival at Gravesend and our receiving timber in the Surrey Commercial Docks.

The table comprises a list of 29 steamers, and it will be found that 376 days were occupied, being an average of 13 days each steamer, in our receiving our portion of the cargo.

We are hampered and suffer great inconvenience and loss by reason of the river being so shallow below and above London Bridge.

Mr. T. W. JACOBS, Jun. (p. 193): (3739) Craft are required to be in attendance for many days before the shipowner can, or does, in fact, deliver. The docks in consequence become congested with craft.

(*i*) The want of accommodation for the quick discharge of vessels in the docks, owing to the absence of modern appliances and methods, and in the river for vessels desiring to discharge there by reason of insufficient mooring accommodation. (*j*) The want of sufficient mooring accommodation for barges in the river.

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Mr. R. DEERING (p. 204): (3962) Craft are required to be in attendance for many days before the shipowner can, or does, in fact, deliver.

If such craft are not in attendance the goods are immediately put upon the quay and become subject to charges; or if on the quay for ship's convenience, charges are immediately claimed, which the lighterman must pay before he can get his goods. It is not unusual for me to have a barge detained in the dock for three weeks waiting to receive its cargo.

With regard to the export trade, I complain that large numbers of loaded lighters are ordered into and are taken into the dock at one and the same time, in order that the loading vessels may have a choice of goods. Such barges are frequently kept waiting for a long time, and are passed on from one ship to another.

Mr. WM. VARCO WILLIAMS also stated (p. 198): (3835) Take, for instance, a tug with six barges in tow, containing, say, 800 tons of goods. Leaving London Bridge at high water, she will be outside the Albert Dock entrance about two hours afterwards. She has, under present circumstances, to lie there with her tow during the remaining five hours of the ebb, and probably two or three hours of the flood, before the barges are allowed in. By the time the craft coming out of the dock can be got hold of by the tug it is frequently too late to save high water even up to London Bridge.

Many more similar extracts could be adduced as to the dilatory systems in use for barge services, resulting, of course, in equally emphatic complaints from the merchants of delays in deliveries and consequent losses, of which many extracts could be given.

Anything that will operate to remove these obstructions must tend to improve the conduct of business and cheapen the products of trade, thus benefiting the barge-owners, the merchants, the labourer, and ultimately the consumer.

The dockisation of the river will further benefit the barge business by bringing into use the many miles of lower river frontages for manufacturing purposes, for which they are now useless, owing to the wet character of the low lands and the inability to use the river front for wharfage for want of depth of water. These lands are the ideal sites for factories, with cheap water carriage for their material and products, and the advantage of removal from the residential areas of London.

To both barge-owners and their licensed lightermen there is also the further inestimable advantages of steady continuous work, instead of tide-waiting; carried on under reduced risks of navigation, with free entry and exit of the docks at all hours.

Part of the enormous waiting losses undoubtedly falls on the barge-owner, the avoidance of which losses means a considerable gain; besides which each barge can do more work in a given time, thus reducing the capital outlay for trade stock.

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NORTH WOOLWICH GARDENS.

GREENWICH PIER.

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[*To face p.* 138.]

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PURFLEET. BOTANY GARDENS.

PURFLEET. BOTANY GARDENS.

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SECTION XXI.

THE THAMES AS A HIGHWAY FOR PASSENGER AND PLEASURE TRAFFIC.

This aspect of the question is not one of the most important, but may be regarded as a side issue in which, however, a very large part of the population—who care little for the Port business—will take an abiding interest, for it is matter of common knowledge and comment that the river, as a highway, has been grossly neglected and fallen into disrepute for many years past. An investigation of the causes that have operated to bring about these conditions and of the methods that may remove them will, therefore, be of general interest.

The upper non-tidal river does not, however, come under the above description in any degree, on the contrary its use for pleasure boat traffic of all kinds has grown continuously, keeping more than pace with the population.

To go back 40 or 50 years we find that there were many popular resorts on the river banks within easy reach of the City. Steamboats ran at frequent intervals between Woolwich and the up-river districts as far up as Putney; other steamboat services went up to Kew and Richmond and down to Purfleet and Gravesend. There were boats and "hoys" to Margate and Ramsgate; steamers to Deal, Dover, Harwich, Ipswich, Felixstowe and Walton-on-the-Naze, and several longer routes, and all these were well employed and patronised.

The present time finds the London County Council trying, at a considerable loss, to establish a cheap local summer service of steamboats. The Thames Steamboat Company—the present representative of the old "Citizen" and "Ironboat" services—has run an up-river service to Chelsea; but the Gravesend, Woolwich and Purfleet section has been long dead.

Of the longer services there are a few fine boats such as the "Marguerite," "Royal Sovereign," and "Koh-i-Noor" run during the height of summer, but many of the routes are unserved and derelict.

What has brought about these changes and converted the river from a highway into a dock? The popular resorts are either gone or dead and no others have taken their place. The steamboat piers and the boats are better found in every way, but there is no life in the traffic; it does not pay; the public do not believe in it and refuse to patronise it because of its many disabilities.

The chief agencies that have brought it to the present state of inanition are undoubtedly the growth of shipping and barge traffic and the tides. The shipping and barge traffic are natural growths, inevitable, as following the growth of London; but the tides are the same as ever, in which, in fact, an improvement in the condition of the water and foreshores is even to be noted, since the main drainage and sewage treatment have been in force. The river has also been embanked in parts with pleasant and well-kept gardens, but still, although there are nearly three times the population,

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cheap fares and better boats, the traffic is far below the accommodation. There are no competing shore, rail or tram services to account for the loss on the greater part of the routes.

Some of it is attributable to the dying out or degeneration of the old riverside resorts, and some to the parallel omnibus and underground services between the City and Westminster; but the need for riverside resorts, for cheap river trips, boating and so on are greater than ever as recreations for the working people, whose range of healthy pastimes is becoming more and more restricted.

The papers have published many eloquent lamentations over this degeneracy, but the only practical outcome as yet is the unfortunate steamboat service.

That the tides are the chief and standing hindrance to the realisation of a popular use of the river is easily demonstrable. The rapid current makes navigation difficult and dangerous, causes delays and irregularities in the time-table, blundering in approaches to the piers, demands greater care and more men in charge everywhere, chokes up the mid-river fairway with shipping and craft of all kinds, fills the water with mud and unwholesome smells, and at low-water confines the traffic to a narrow channel—often too shallow above bridges—so that the boats go aground or cannot easily reach the piers. Irregular service is a powerful deterrent with the public who get, on land, services of great regularity. Blundering about the piers, again, discounts the popularity of this mode of getting about. The distance from the streets and bad approaches of many piers are deterrent factors, and people are now more sensitive to smells and discomforts, which they are not called upon to put up with elsewhere. The reports presented to the London County Council admit all these objections, but do not admit that they are removable.

The use of pleasure boats, launches, &c., in the Port section of the river is certainly dangerous and impracticable under tidal conditions, and if attempted would, there is no doubt, be discouraged or prohibited by the authorities. Above London Bridge the dangers are chiefly due to the steamboats and the tides, the barge traffic does not constitute a serious danger or difficulty. Below Greenwich, also, the tide constitutes the chief objection, if we except the smells of the chemical works, which are rather strongly in evidence down to Barking.

It will be evident now that the greater part of the objections detailed above would be removed if the tidal action ceased and the river was maintained at high-water, for the results would include:—

1. Still water, always at high-tide level, with no perceptible current.
2. Clean fresh water in place of a mixture of fresh and salt water with mud, and absence of exposed muddy foreshores.
3. Absence of the characteristic sewage scent of the water.
4. Piers and landing places for all sorts of pleasure or passenger boats could be placed close to the shores.
5. These piers would be fixed, not subject to rise and fall.
6. Deep water at all times and for the entire width of the river.

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GREENWICH OBSERVATORY AND PARK.

AT PURFLEET, THE RIVER SIDE.

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7. Removal of the obstructions of floating tiers of ships and barges from the mid-river fairway to shore moorings.
8. Absence of drifting and swinging with the tide, which are the causes of the greater number of river accidents.
9. Safer navigation owing to the better handling of all vessels, and the distribution of the traffic all over the working day and night instead of its being concentrated into a few hours at high-water.
10. Regularity and certainty of the steamboat service at all times and the possibility of a winter service.
11. It will be possible and popular to introduce steamer services down-river to all the old resorts, which are still capable of becoming places of recreation, and only need a cheap and efficient service of boats to render them again popular.
12. Nearly every part of the river will be safe and pleasant for pleasure boats. Their presence may not be desirable between London Bridge and Greenwich, but above bridge to Teddington there is a magnificent stretch of river which would become a boating lake, with refreshment houses and gardens at many suitable places on its banks.

This change in the river will greatly add to its usefulness, its appearance and profit, employing a large number of men and boats, providing a new source of pleasure for the people and a new river industry.

The following article from the *Field* puts this question of the possibilities of a pleasure traffic from the popular point of view :—

It is remarkable that the Thames has been so little used, and has become so unpopular as a highway. An effort is now being made to popularise its waters by a service of new steamboats under the auspices of the London County Council, and another service of steamboats by the Thames Steamboat Company, Ltd. These, if conducted on popular lines, will do something to bring once more into service the Thames as an avenue for human traffic. But the regeneration of the Thames, its cleansing, and the beautification of its banks will only be effected by the construction of the proposed barrage at Gravesend, with the resulting removal of tidal action and the maintenance of its waters permanently at high-water level. This proposal has been before the public for some time past, and has been very generally approved subject to its being proved to be practicable. As to this, two of the greatest living expert authorities have reported that it is practicable, and that it offers very important advantages over any other proposal yet suggested for solving the entire problem of the Thames, its port, traffic, cleansing, finances, and its beautification.

It is with this last that our present purpose is concerned, not because it is the most important, but because the commercial and technical aspects of the subject have been much discussed, while very little has been said about its lighter side ; yet, to the " man in the street," the resident, the visitor, and, indeed, to everyone who considers it apart from a purely business point of view, the look of the river, its appearance from every direction, the opportunities it will afford for pleasure purposes, boating, sailing, fishing, racing, riverside trips, and garden places of entertainment and recreation, will, after all—though not of paramount money value—be the clear and standing evidence that will appeal to him strongly as proof of the improvement of the river as a result of the barrage.

There are many still living who can recall the old riverside resorts, which were in their prime fifty years ago—Cremorne, Rosherville, Vauxhall, and their memories are matters of history, but

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history often repeats itself it is said—with improvements, of course—and it may not, in fact, need not, be long before Thames-side blossoms out once more into gardens and waterside retreats, and carries on its cleansed and polished surface whole armadas of pleasure craft of every description. At the present moment all this class of traffic is rigidly confined to the upper river, because there is no tide there and no mud, but clean water, pleasant river banks, waterside hostelries, tea gardens, boating clubs, hotels and accessories that would be impossible with a tidal river. The port business is practically confined to the stretch of the river below London Bridge, above which it would be of great public advantage if the embankments were extended on both sides to form public promenades and avenues for street traffic, which, thus diverted, would relieve the main thoroughfares.

The embankments, beautifully laid out as they are, and well kept, would be much enhanced in value as promenades if the river was always at high water, and clean. Now one has to take the off-chance of its being high or low water, as the main factor on which the pleasure of a walk on the embankment depends. If it is low water, the river is dirty with broad margins of foul mud; at high water the prospect is much finer, but still the nose is often offended, because the water fronting the visitor is not from up the river but from down below, from the area fouled by the offscouring of the great city, accumulated for months past, and washed up and down continuously, day and night, past the upturned noses of its citizens.

Let us see, then, in what way and where it is possible to improve the river front when the tides have been banished. In the first place the river will have become a fresh-water lake, always remaining at one level (Trinity High Water, which is about the level of ordinary spring tides), never, even in flood seasons, rising more than a few inches above this level, and having a slow, almost imperceptible, downward current at all times. In such a river-lake it is evident that boating would be possible and pleasurable at all points where the business traffic is not too great to restrict it or make it dangerous.

First in importance must be placed the steamboat service. This has been always, and will be now—until the river is dammed and the tides kept out—run under very unfavourable conditions, such, in fact, as have made it both unprofitable and unpopular; because, with the tides running, the boats must be of sufficient power to go at fair speed against tide. The piers are difficult of access and approach, rise and fall with the tides, and provide very little depth of water at low tide for the steamers; in fact, above London Bridge they often go aground, and are necessarily confined in navigation to the middle of the river.

The steamers also stir up the mud, and thus create around them smells that do not add to pleasure or enjoyment. The piers are most unattractive, unsightly erections, suggestive of docks and barges instead of joy, and the boats themselves are built to match the piers, in which respect the new County Council boats will not make much improvement. The entire service and its surroundings is squalid, drab, and depressing to a degree, so that it is not difficult to see why it has failed, and may yet fail, to attract the public. And yet, what a boon it would be to the poor workers if they had the run of their own river under pleasurable circumstances, and at a cost that they could afford.

Now let us turn to the other picture, with the Thames a high-water lake and see how it will help the steamboat service. In the first place the steamboats need not be nearly as high powered, or, what is better, will be able to run with the same power safely at much higher speed than now, because there will be no tide to contend with. With a cleaner river the boats can be kept cleaner and brighter; there will be no mud stirred up and no smells to assail the nostrils. The entire width of the river will always be available for their navigation, and the piers can be removed close to the river side, where, being fixed, they will be much more accessible than now. The navigation also will be very much safer and easier than is now the case with the tides running. There will, therefore, result a great increase in the number of passengers, because the full, clean river will attract vast numbers to have a run on it who will not look at it in its present condition, and those who know how to cater for the public will soon provide for the newly-acquired taste for water trips.

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But where can the people go ? Up river, above Westminster Bridge, besides the well-known places of resort, such as Kew, Richmond, Battersea, Teddington, and others, there are many miles of river banks capable of being developed into riverside gardens, parades, walks, tea houses, &c. The demand will create the supply. Down river, below the crowded shipping district, there are Greenwich, with its hospital and park, Woolwich (north and south), with their riverside gardens and their public parks. Purfleet has splendid natural beauties that can easily be developed into an attractive pleasure resort. There are already old-fashioned chalk pit gardens and cliffs, tea gardens, and other attractions of a primitive kind, struggling for customers, that would go in thousands if an adequate steamboat service on the Thames lake was started. Further down, Gravesend and Tilbury possess great natural attractions, if the approach to them by river is made easy and pleasant. Rosherville is still unsurpassed for its natural beauty, but cries out for visitors. And below the barrage will be the sea, the ever-moving shipping, the pilot boats, the departures and arrivals of ships, a moving panorama of intense interest that can be watched from the barrage parade, and will be a source of unending attraction. The passage of the shipping through the locks, the sea on one side and the lake on the other, will afford plenty of amusement and perhaps sometimes of excitement. All these river attractions will fall naturally into line and increase as soon as the river itself has been made what it ought to be, a clean, fresh-water lake.

But, besides the steamboat services, it is certain that we shall see a rapid development of the boating and aquatic sports now confined to the upper river. The row boat, the launch, and in places the houseboat will be very much in evidence, and in the lower reaches sailing and yachting can be indulged in with every element of success. Regattas will again come into vogue, and under more favourable conditions than obtain at any seaside place, because carried out in a well-protected lake of ample area, where the sport can be seen from both banks.

If we cannot nowadays revive the memories and scenes of old Thames, we can at least improve on them and bring them up to date. It is evident from the foregoing that the pleasure traffic will add a large volume of employment for boatmen and riverside people, who now complain of the decay of the port, and of want of employment. It will also enhance the value of all riverside properties, bring into use river frontages, marshes, and vast tracts bordering the river, now derelict and useless.

A reliable and regular boat service will also enable city people to live at places on the river side, many of which cannot be reached by rail. The cheapness of the boat service will make these places attractive to working people, and Professor Flinders Petrie's proposal to remove the workpeople and factories down river to the border lands of Kent and Essex may yet be realised, where they will enjoy better and healthier conditions of living than in the crowded East-end of London.

Hamburg, one of London's greatest rival ports, has long enjoyed the advantage of such a locked water area or artificial river-lake in its beautiful Alster Basin, where the pleasurable aquatics we have described have long been part of the popular recreations of the townspeople, and there is no reason why London, with its dense, hard-working population, should not enjoy equal or even greater advantages by the conversion of its river into another Alster Basin.

The importance of the pleasure traffic is "shewn by the fact that in 1906 the number of pleasure boats standing registered in the books of the Thames Conservancy were: 11,382 small rowing and sailing craft, 862 launches, and 193 houseboats." LORD DESBOROUGH, Ev. Com. on Canals and Waterways.

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SECTION XXII.

MINOR QUESTIONS.

Are the Tides Beneficial in Changing the Air of London?

This is not a scientific proposition, but a popular and newspaper notion, not traceable to any definite source; yet it is to be found repeated by men of position (who might be assumed to have satisfied themselves as to a basis for the suggestion), such as public medical officers and others.

A very slight examination of the idea involved quickly dispels the illusion.

The movement of water has no effect whatever upon the movements of the atmosphere. The reverse, however, is a common phenomenon. The sea does not move the air, but the air drives the sea. Wind moves water on the surface, driving it in waves and ripples. The travel of tides, therefore, does not bring on their surface a change of air.

The rise and fall of the tide certainly does displace an equal volume of air vertically; but this volume over the lower Thames would only amount to 107 million cubic yards in 12 hours. But the quality of this air is very questionable. It is grossly tainted with the smells and emanations of the river and its muddy foreshores. To raise this foul air and pour it out over London streets is a change of air of a very undesirable character.

But a very slight breeze blowing across the river at, say five miles per hour, will carry across the river 123 times the quantity that the tides displace in 12 hours, as noted above, and air of a much better quality.

The river is a great devourer of oxygen, which is absorbed in large quantities in the chemical and bacterial processes of cleansing described on p. 118. This necessary absorption is more rapid in still water than in running tides, and, therefore, wind currents are necessary to provide the changing air contact with the water essential for this process, so that a still-water lake is more effective than a tidal stream. (*See* p. 66.)

Is the Salt Water of the Tides Beneficial?

To this question the answer must again be in the negative. Like the last, it is a popular delusion, probably due to newspaper science.

It has been shown in Section XII. (p. 67) that salt water tends to deposit organic pollution as sludge; this sludge ferments and gives off nauseous gases. The deposition prevents the natural bacterial purification which is always going on in all rivers, and which, therefore, proceeds most rapidly and effectively in fresh water. Many extensive series of experiments have established this fact beyond question.

Salt water is also heavier than fresh, and remains chiefly under the fresh water. Thus we have seen (p. 69) that on the commencement of the flood tide it runs up along the bottom, some time before the ebb has ceased on the surface, and is the chief cause of the up travel of lower river silt.

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The blending of salt water with fresh river water also renders the mixture unsuitable for most industrial purposes. There are numerous and large manufactories on the Thames banks that could, and would, utilise the river water for various purposes, where very clean water is not needed, but are debarred now both by the saline character of the water and by Thames Conservancy Board regulations prohibiting its use.

Other large factories have long used it, but would be much benefitted if it were wholly fresh. In boilers it causes a very dense deposit, and cannot be used for condensers, except of the surface type.

Steamships use it because they are compelled to do so, but would prefer fresh water.

A fresh-water river would therefore be a great benefit to all industrial interests, and its water could thus be a considerable source of revenue, without injury to the river; besides which it would deposit less mud, produce less smell with an equal amount of pollution, and more rapidly oxidise and dispose of its pollution by bacterial action.

Does Tidal Action Cleanse the River?

This is an assertion universally made and repeated by both experts and almost every type of writer on the Thames.

So that it is desirable to know what is the cleansing action, if any, and whether its continuance is necessary to the preservation of the river.

A perusal of Section V. shows that the real balance of cleansing action is due to the upland water, or, strictly speaking, to the over-balance on the ebb which it creates.

The tides flow up 5½ hours and down 6½ hours; the difference of about one hour in favour of the ebb is due to, and varies with, the upland water (which has been backed up during the flood tide), adding its volume to the ebb, and to difference of velocity, which has been found to be greater on the flood than the ebb. This last point is more in evidence on other rivers than the Thames, where it frequently results in a "bore" or tidal wave, but is present to some extent in all rivers.

Were the upland water eliminated, therefore, the balance of scour of the tides would be against the discharge of silt, and the river would silt up. This was generally admitted in a long discussion on this subject before the Institute of Civil Engineers in 1881, when most of the leading hydraulic engineers took part.

The so-called cleansing action of the tides is, therefore, the scouring up of the bottom and foreshores, which is greatest on spring tides and least on neaps. But unless this mud, thus scoured up into suspension, is removed from the river there is no cleansing whatever, but merely an everlasting stirring up and circulation of mud, that might be better left unscoured. The removal of it is therefore not the work of the tides, but of the over-balance of the upland waters.

For this reason the contention of engineers that the tidal action in a tidal river should not be reduced is correct, because it is the scouring or stirring up factor in the removal of sediment; and the further contention that the quantity of upland water should not be permitted to be reduced below a certain minimum flow is also correct, because it is the upland water which constitutes the actual removal factor of

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the tidal flow, carrying out of the river (as described on p. 27) at every ebb an equal quantity of the stirred-up and therefore foul tidal water.

But all this goes to show that while tidal action is beneficial in an open river, which has been formed by tidal action, so long as it remains tidal, it is not therefore necessary; nor is it necessary that the river should remain open, and therefore tidal; for it is the tidal action which creates the condition of foulness, which requires the combined tidal and upland action to remove.

For if the river had been non-tidal from ancient times, its width would have been very much narrower and its *régime* totally different. There would have been a continual down flow, greater or less according to the rainfall, and always sufficient, in the narrow channel, to remove silt and keep the channel open, for all rivers form their own channels to correspond with their flow.

But now that the river has been formed by tidal action into a wide channel, the closing of it into a lake entirely removes the necessity for scour, because there is no longer the up drift of material to be again scoured on the ebb, and it has been shown (p. 77) that, compared with the up drift, the deposit from upland waters is quite insignificant in itself. A very large number of rivers throughout the countries of the world are either a series of such lakes, or have such lakes in part of their course. The lakes do not silt up, require no scour, and do not become stagnant or foul; in fact, are the best of all waters, because they are the best-conditioned for natural purification. These lakes, in fact, dispose of most of the organic sediment brought down by the rivers.

Will the Tides below the Proposed Dam Rise to Greater Heights and cause Greater Flooding below Gravesend?

No engineering expert has made this statement, but it has been frequently mentioned as likely to happen, apparently on the supposition that the opposing of a barrier across the tide must cause the waters to pile up.

The idea is unfounded, however, and fails to appreciate the fact that the tide flows up the river, not because it is pushed up from behind, but because the river invites it, as it were, its level being then lower than that of the sea and estuary. But if the river is closed, there is then no such attraction for the tide, which will only flow towards a lower level.

Up to Gravesend, therefore, the tide will be that of the estuary itself, plus the short piece of river below the dam, and these estuary tides are lower at high water than up river, so that there will never be floods of such height as now occasionally occur in the lower river and estuary, and the low-water line will not fall so low as now; which latter fact constitutes an immense advantage, in giving greater draught for vessels in the upper channels of the estuary (where this effect will be most in evidence) and in reducing the need for dredging them.

The difference will be probably greater at low water than at high, the range of tide generally when reduced taking that form, as at Glasgow and on the upper Thames itself. (*See* p. 75.)

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Ice in the Tidal River.

An occasional incident in the Thames occurring but rarely is the formation of ice in severe winters, such as those of 1855 and 1886.

In the upper river, where there are no tide currents, ice is more readily formed, and the river becomes in places frozen over owing to absence of rise of tide and insufficient traffic to break it up.

In the tidal river ice is only formed in patches in backwaters, &c., to which is added ice coming down from the upper river. The drift of the tide carries these patches and floes up and down, and in their course they accumulate against all floating obstructions, such as piers and tiers of vessels and barges, often to such an extent as to break them adrift, when a good deal of damage must necessarily follow, many barges being sunk in this way. If the rigorous weather lasts for many days, these accumulations, instead of drifting out of the river, increase rapidly, and on occasions have choked up the crowded part of the river from shore to shore.

The rarity of such occurrences makes them of little account, but it may be worth while to see to what extent their effects will be modified by the construction of a barrage.

That the creation of a still-water lake will considerably facilitate the formation of ice is, of course, evident. But ice can only be formed or accumulate in thickness in untroubled waters. In the Thames there will be such a large and ceaseless traffic of steamers and vessels of every class throughout the day that it is impossible for ice to form or become of such thickness as to seriously obstruct traffic. If severe weather continues, ice-breaker tugs can be employed to keep it cut up, if necessary. There will, however, be no drifting of floes or breaking adrift of barges or vessels, and no damage done such as occurred under tidal conditions, there being no perceptible current and no other agency than the wind to cause drifts.

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SECTION XXIII.

THE FINANCIAL QUESTION.

Cost, in a work of this kind—if the work itself is determined upon as being the best for the purpose in view—must necessarily be a secondary consideration, provided that it is not so heavy as to be prohibitive.

But, besides the mere capital cost of the works proposed, a more important financial question is the effect on charges and expenses within the Port; for these are daily and annual charges which fall upon the goods and are paid by the consumer, thus determining cheapness and, as a necessary result, demand.

The capital expended merely appears in the form of annual interest and sinking fund on loans. So that the financial question naturally resolves itself into two parts—capital outlay and current expenses—and must be considered under these two headings.

There is also the general question of capitalisation, as compared with the existing system and any other alternatives, such as those proposed by the Port of London Commission, the City Corporation, the London County Council, and the London Chamber of Commerce. Each of these bodies put forward a scheme for dealing with the Port from its own point of view, besides others of a less authoritative character.

Another aspect of the cost, not to be disregarded, is the effect, financially, upon other public services affecting the Port and the London district, as well as of all the districts bordering the Thames, for these may be indirectly benefited or injuriously affected by any proposal to alter the conditions obtaining in the tidal river; and, further, the cost of compensating disturbed interests must necessarily be a question of great magnitude, in view of the difficulty of justly awarding compensation, and the suppression of bogus or extravagant claims which always arise in great force in connection with any such public undertaking.

Capitalisation of the Port.

The fairest method, but a very difficult one, of estimating the comparative economic value of the proposed works, would be one based on the present capitalised value of all the properties abutting on the tidal river—as determined by their annual profits—as compared with the prospective value of the same after dockisation of the river; the cost of the works to be charged against those properties or interests most benefited in proportion to their appreciation in value.

Another method, somewhat easier, would be to estimate the appreciation or depreciation of each separate property or interest affected, setting them out in a *Dr.* and *Cr.* account, the appreciated properties to be made to pay the compensation due to those depreciated and the cost of the works, or—as the latter can be capitalised on loan—the interest on the loan. Estimates based on either of the above principles must, however, give rise to great divergence of opinion as to their reasonableness, and it will only be possible for us to take the more obvious cases of advantage or disadvantage and prepare an estimate on them which must of necessity be incomplete. But,

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apart from capitalisation, it is possible to estimate the total current expenditure in the Port, under the different conditions as proposed by various schemes for management, with considerable accuracy, and this method is the one adopted in the following investigation.

It may be fairly assumed that in a public work for the improvement of the Port of London, and designed to benefit most directly the trading interests of the Port, these interests ought to pay the cost of the works or the annual charges on the loan raised for this purpose; but this distribution of the burden ought clearly to include all those benefited directly or indirectly, and not be assessed solely on those immediately concerned in the operations carried on in connection with trade in the river, unless through such assessment the more indirect beneficiares can be reached equitably. There are thus those directly and those indirectly affected who should be treated on different lines. These include :—

INTERESTS DIRECTLY AFFECTED.

On the Riverside :—

Dock Companies.
Dry Dock Owners.
Wharfingers.
Manufacturers.
Canal and Railway Docks and Quays.
Private Frontagers.
Authorities owning public roads, bridges, piers, moorings, stairs, embankments and grounds fronting the river, and sewerage works discharging into the river.

On the River :—

Shipowners.
Shippers and Merchants.
Barge Owners.
River Steamboat Owners and Passengers.
Tug Owners.
Boatmen, Watermen, Lightermen.
Pilots.
Seamen.

INTERESTS INDIRECTLY AFFECTED.

The general public of London and elsewhere who purchase the goods landed.
The great railway and canal companies who carry the goods.
The carriers other than barge owners and railways.
Shopkeepers.

It seems obvious that the foregoing diverse classes or interests cannot all be included in one category or assessment. It should, in fact, be a matter of careful enquiry by a Commission or Court of Arbitration, in order that dues and charges to be levied shall fall on those most able to bear them, because most beneficially affected. The dues should be, if possible, levied in the form of simple tonnage rates, easily ascertainable

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THE FINANCIAL QUESTION

Cost, in a work of this kind—if the work itself is de
best for the purpose in view—must necessarily be a seco
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the charges, because they carry the goods into other
s can only in this way pay their share of the charges of the port
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The fair
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p must be the estimation of the cost of the proposed works and of
mentary pumping and other works necessitated by the construction of the
From such an estimate the annual charges for maintenance, interest, sinking
and management can be estimated.
The Engineer's estimates for works, &c., are as follows :—

CAPITAL OUTLAY.

ESTIMATED COST OF THE PROPOSED WORKS.

The works to be constructed at Gravesend are comprised in the following estimate:—

ESTIMATED COST OF CONSTRUCTION OF THE PROPOSED DAM ACROSS THE RIVER THAMES WITH LOCKS, WEIRS, GATES, ROADWAY, TUNNELS, BRIDGES, APPROACHES, POWER HOUSE, MACHINERY, PILOT TOWER AND OTHER WORKS CONNECTED THEREWITH, AS SHOWN IN THE PLANS AND SECTIONS AND FIGURES, AND DESCRIBED IN SECTION VII.

Preliminary.	£	s.	d.
Engineering charges	120,000	0	0
Parliamentary, legal and preliminary costs	200,000	0	0
Carried forward	£320,000	0	0

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...es for revenue, the main principles to be kept in view are ... of the Port, equitable incidence of charges as between ...harves and docks, barges and railways, &c., absence ...n of working dues and of delays.

...es levied, costs incurred, or labour involved, in ...s easily demonstrable that all such outlay falls ... cost to the consumer, and to this extent ...ng to reduce, the volume of trade.

...ENUES.

...rd, so far as derived from the lower ...odation, tolls, pier dues, dredging,

TOTAL ..

SUBSIDIARY

(1.) Pumping ... RD BELOW TEDDINGTON LOCK.

...clude the pumping stations desc... 1905.
...ng drains and outfalls. £ s. d.
...ost of these, as estimated by Mr. Hennell, M. 65,198 14 6

(2.) Strengthening River Walls 16,265 8 9

If determined upon, and the walls constructed as shown ... 00 0 0
Hennell's estimate of the cost of 15¾ miles of such inner works ... 16 6
puddle trench (as Fig. 33, page 103) is taken at £791,300. 0 11

SUMMARY OF COST.

	£		
Works and compensations	3,821,600		—
Subsidiary works	474,400		8
River walls	791,300	0	
GRAND TOTAL	£5,087,300	0	0

EXPLANATORY NOTES.

The *Works* required and scheduled above may be considered as amply provided for in the Estimates.

For *Land and Compensations* the sum of £980,000 is provided. This item must of necessity be a speculative one, as it is not in the power of any actuary or valuer to state with any approach to probability the sums that might be awarded to persons having properties or interests affected by a Barrage, and it is certain that heavy and persistent demands will be made and injurious damage asserted in numerous cases where none actually exists. Attempts may be expected to be made to attribute wet sub-soils, dry sub-soils, deficiencies of drainage, accumulations of storm waters, unsatisfactory well waters, and other more or less irrelevant or indirect damages as due to the maintenance of a permanent high-water level. It may be assumed, therefore, that an Arbitration Court will require to be constituted to make awards in all these

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and proportionately assessed on the basis of profits, or value in bulk, so as to represent as nearly as may be a fair charge on the earning capacity of the goods.

Of those directly affected, the six first-named stand to be most directly and materially benefited, because they abut on the water frontages, and will gain considerably in quick despatch, continuous work, cheap labour and many other details.

The remaining authorities and owners named will benefit by the existence of more stable conditions in the river, less damages, repairs and interference. In the case of sewerage authorities their effluents will have to be pumped as described (p. 103), and they will then have the advantage of a continuous clear discharge into the river at all hours, not subject to tides, and their outlets will be raised to above T.H.W., and always accessible.

Floating or traffic interests should contribute in proportion to their charges for services, so far as the first five above named are concerned. They take a toll on the goods for freight, barging and other forms of water carriage, which add to the cost to the consumer.

The remaining three classes represent labour only, and cannot be expected to contribute, beyond the payment of such annual fees or licenses as may be deemed equitable.

But the indirect interests—represented chiefly by the ratepayers, who will have to pay whatever assessments are levied on the goods in the form of a proportionate advance in price, can hardly be expected to pay a second direct charge, in the form of a rate, though such rate would reduce the direct charges, which must in any case fall upon them, however assessed; for on whomsoever it may be assessed it will increase the cost and market price of the goods, and thus fall automatically on the consumer.

The railway and canal companies and other land carriers, however, should contribute a fair proportion of the charges, because they carry the goods into other districts, and such districts can only in this way pay their share of the charges of the port through which they derive benefit.

The first step must be the estimation of the cost of the proposed works and of such supplementary pumping and other works necessitated by the construction of the dam. From such an estimate the annual charges for maintenance, interest, sinking fund and management can be estimated.

The Engineer's estimates for works, &c., are as follows :—

CAPITAL OUTLAY.

ESTIMATED COST OF THE PROPOSED WORKS.

The works to be constructed at Gravesend are comprised in the following estimate:—

ESTIMATED COST OF CONSTRUCTION OF THE PROPOSED DAM ACROSS THE RIVER THAMES WITH LOCKS, WEIRS, GATES, ROADWAY, TUNNELS, BRIDGES, APPROACHES, POWER HOUSE, MACHINERY, PILOT TOWER AND OTHER WORKS CONNECTED THEREWITH, AS SHOWN IN THE PLANS AND SECTIONS AND FIGURES, AND DESCRIBED IN SECTION VII.

Preliminary.	£	s.	d.
Engineering charges	120,000	0	0
Parliamentary, legal and preliminary costs	200,000	0	0
Carried forward	£320,000	0	0

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ESTIMATED COST OF THE PROPOSED WORKS—*continued.*

	£	s.	d.
EXCAVATION: *Works.* Brought forward	320,000	0	0
In chalk and gravel—cubic yards, 360,000, at 10s.	180,000	0	0
Granite masonry—176,800 cubic yards, at £7	1,237,600	0	0
Concrete hearting—371,000 cubic yards, at £1 10s.	556,500	0	0
Opening bridges and machinery	35,000	0	0
Lock gates, sluices and machinery, bollards and capstans ..	163,000	0	0
Tunnel lining and formation	30,000	0	0
Iron and timber stagings and falseworks, cast iron and steel cylinders and pier cofferdams	243,500	0	0
Metallings of roads	14,000	0	0
Power houses, water, electric light and gas services, signals ..	19,000	0	0
Footways and parapets	16,000	0	0
Stairways, river steps, &c.	9,000	0	0
Six steam tugs, launches, and police boats	18,000	0	0
	£2,841,600	0	0
Land and compensations	980,000	0	0
TOTAL	£3,821,600	0	0

SUBSIDIARY WORKS.

(1.) Pumping Stations.

These will include the pumping stations described and scheduled in Section XVI., with connecting drains and outfalls.

The cost of these, as estimated by Mr. Hennell, M.Inst.C.E., amounts to £474,400.

(2.) Strengthening River Walls.

If determined upon, and the walls constructed as shown in Fig. 32, page 105. Mr. Hennell's estimate of the cost of 15⅓ miles of such inner works and of 22⅔ miles of puddle trench (as Fig. 33, page 103) is taken at £791,300.

SUMMARY OF COST.	£	s.	d.
Works and compensations	3,821,600	0	0
Subsidiary works	474,400	0	0
River walls	791,300	0	0
GRAND TOTAL	£5,087,300	0	0

EXPLANATORY NOTES.

The *Works* required and scheduled above may be considered as amply provided for in the Estimates.

For *Land and Compensations* the sum of £980,000 is provided. This item must of necessity be a speculative one, as it is not in the power of any actuary or valuer to state with any approach to probability the sums that might be awarded to persons having properties or interests affected by a Barrage, and it is certain that heavy and persistent demands will be made and injurious damage asserted in numerous cases where none actually exists. Attempts may be expected to be made to attribute wet sub-soils, dry sub-soils, deficiencies of drainage, accumulations of storm waters, unsatisfactory well waters, and other more or less irrelevant or indirect damages as due to the maintenance of a permanent high-water level. It may be assumed, therefore, that an Arbitration Court will require to be constituted to make awards in all these

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cases and thoroughly sift the evidence. In giving its awards, the question of betterment should also be considered, as many properties and interests will undoubtedly be greatly benefited.

Subsidiary Works.—The Estimates assume that the main drainage storm overflows, and all marsh and other drains and effluents will be dealt with on the plan proposed in Mr. Hennell's Report (Section XVI., page 101); but there are alternatives, the comparative cost of which should be considered, though in a question of drainage, efficiency should be the main consideration.

Strengthening the River Walls—£383,300 and £408,000. — The writer considers it extremely doubtful if this work will be found necessary. Mr. Hennell admits (and the cross-sections of the river bed, page 23, show) that it is impracticable to carry the foundations of puddle cores deep enough to cut off percolation from the river into the marginal lands; so that unless the walls require strengthening to resist pressure in places, the sum charged under this head need not appear in the Estimates. There is no evidence that the walls are anywhere insufficient. The very few cases of failure in their long history have been results of either exceptionally high tides driven by a strong wind washing through the top of the wall and rising several feet above T.H.W., or from dredging or slipping in of the sandy foundation. Neither of these can occur if the river is maintained at T.H.W., because the permanent pressure of the water will support the walls and prevent sliding in of loose sandy strata or the foreshores.

It is also very probable that all the marginal lands will in a few years be utilised for riverside factories, which will necessitate the construction of wharves, in which the walls will be embedded, and thus permanently strengthened or superseded by embanked quays, &c.

Parliamentary and Preliminary Costs.—These also cannot be closely arrived at; but, assuming a considerable amount of opposition and the employment of the highest expert witnesses, advocates, lawyers, and engineering, including surveys, studies and other preliminary work, the estimated sum of £200,000 should be ample.

Estimates of Revenue and Expenditure.

Assuming that the Port will be administered by a single Authority, which may be a new Trust, Harbour Commission, or a reconstituted Thames Conservancy Board, and that it will take on it all the services and duties now performed by the Authorities named in Section II., the revenue of the Port Authority will be derived partly from existing sources and partly from new charges to be levied.

Sources of Revenue.

These will comprise the revenues of the Thames Conservancy Board, so far as derived from the tidal river. Any licensing fees or charges that may be authorised as to pilotage, buoying, mooring, lighting, and other current charges, sales of river water for general purposes, tolls for passing the locks of the Barrage, and a scale of rates on goods, adjusted to such a sum as will pay the interest on the value of the water areas of the docks, or such part of them as may be made public in the interests of the Port.

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In assessing such charges for revenue, the main principles to be kept in view are the improvement of the trade of the Port, equitable incidence of charges as between competing interests, such as wharves and docks, barges and railways, &c., absence of preferential treatment, reduction of working dues and of delays.

Whatever charges are made, dues levied, costs incurred, or labour involved, in transacting the business of the Port, it is easily demonstrable that all such outlay falls eventually on the goods, increasing their cost to the consumer, and to this extent restricting, and thereby reducing or tending to reduce, the volume of trade.

EXISTING REVENUES.

The revenues of the Thames Conservancy Board, so far as derived from the lower river, now consist of tonnage dues, rents for accommodation, tolls, pier dues, dredging, licenses, canal companies' payments, &c., as follows :—

REVENUES AND EXPENDITURE OF THE THAMES CONSERVANCY BOARD BELOW TEDDINGTON LOCK.

	1905. £ s. d.
Receipts.	
River tonnage dues	65,198 14 6
Tolls, Pier dues, Dredging licenses	16,265 8 9
Water and Canal Companies	3,500 0 0
Miscellaneous	257 16 6
Dividends on investments, Rents, &c.	16,012 0 11
	£101,234 0 8
Expenditure.	£ s. d.
†Establishment, Law and office expenses, Wages, &c.	26,519 12 0
†Harbour service	7,663 1 1
†River Purification	2,939 2 8
†Mooring service	9,098 1 10
†Wreck Services	1,805 14 1
Piers, Surveys, &c.	3,199 17 5
*Dredging	23,996 6 9
Towpaths and banks, Richmond footbridge, Locks, Weirs, &c.	8,404 0 4
Pensions and allowances	5,809 5 3
	89,435 1 5
To Reserve and Sinking Fund	11,798 19 3
	£101,234 0 8

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With a harbour authority working the Port under non-tidal conditions, the item asterisked on previous page will be eliminated, and the dredging discontinued.

It may be assumed, also, that the payments for services and management marked † will suffice for the similar services of the new Board.

The Dock Companies' revenue for 1899 was £2,311,302.

The Trinity House collects a poundage of 6d. in the £ from the earnings of pilots licensed by them, together with an annual fee of £3 3s. paid by each pilot for renewal of his license, the amount received, including pilotage, being, in 1905, £192,443.

The Watermen's Company derives a revenue from licensing watermen and lightermen amounting to £3,200.

The foregoing existing revenues thus amount to :—

	£	s.	d.
Dock Companies	2,311,302	0	0
Thames Conservancy Board..	101,234	0	8
Trinity House	192,443	0	0
Watermen's Company	3,200	0	0
TOTAL	£2,608,179	0	8

of which Mr. Gomme says " the sum of £2,372,600 falls upon the consumers as taxation of the goods brought to the Port." (*see* p. 164, Minutes of Evidence, Report of Port of London Commission.)

Taking, then, the capital expenditure as a sum of £5,250,000, which could, no doubt, be obtained at about the same terms as Consols or, say, 2¾ per cent., the annual interest will amount to £144,375, and balance-sheets may be drawn as follows to show the amount necessary to cover the interest on construction and other capital costs and sinking fund.

BALANCE-SHEETS.

To give a fair approximate comparison of the cost of running the Port of London under the existing *régime*, as compared with the proposals of the Port of London Commission and of the Barrage proposal, the following balance-sheets are appended :—

(1.) Balance-sheet of the Port as now governed.

(2.) Balance-sheet of the Port under a Port Trust with a dredged river, and having the control of the docks by purchase.

(3.) Balance-sheet of the Port under a Harbour Board with the river maintained at T.H.W. by a Barrage at Gravesend.

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BALANCE-SHEET No. 1.

REVENUE ACCOUNT.—Revenue and Expenditure of the Port of London Governing Bodies in 1905.

(Extracted from the Report of the Royal Commission on the Port of London.)

Revenue.	£	*Expenditure.*	£
Revenue of the Thames Conservancy Board Lower Navigation Fund ..	101,234	Expenditure of the Thames Conservancy Board in the Lower River ..	89,435
Revenue of the Trinity House ..	192,443	Expenditure of the Trinity House ..	145,716
Revenue of the Watermen's Company	3,200	Expenditure of the Watermen's Company	3,130
		Amount expended on the Port	238,281
		Balance expended elsewhere ..	58,596
Amount levied on the trade of the Port	£296,877		£296,877

BALANCE-SHEET No. 2.

REVENUE ACCOUNT.—Estimated Revenue and Expenditure of the Port Authority, with a Tidal River Dredged to a Low-water Depth of 30 Feet to the Albert Docks and to 20 Feet above same and having Control of the Docks by Purchase, as Proposed by the Port of London Commission.

Revenue.	£	*Expenditure.*	£
Existing Revenue of the Thames Conservancy Board	101,234	Annual Expenditure of the Thames Conservancy Board	89,435
Existing Revenue of the Trinity House		Interest on Loans for works recommended by the Port of London Commission; total capital cost, £7,000,000, at 2¾ per cent. ..	192,500
Existing Revenue of the Watermen's Company		Annual increased guaranteed interest on Dock Stock taken over by the Port Authority (*see* p. 161) ..	90,000
Present revenues to be discontinued and charges for licenses, &c., made by the Port Authority, also for lighting, buoying, &c., estimated at (Pilotage not included)	40,000	Sinking Fund on Dock Purchase Capital, £30,000,000, at 1½ per cent. per annum	462,000
Deficit to be made up by charges on Shipping or Goods .. .. .. (Equal to a levy of 10d. per registered ton of Shipping entering the Port.)	700,701	Increased Fees to Members (40 at £200)	8,000
	£841,935		£841,935

The Author estimates the Annual cost of maintaining the depth of the River by dredging (*see* p. 72), at per annum, 16 dredgers at £10,000 each = £160,000; annual cost of the compensations for Injuries to River Walls and premises (allow) £50,000; which sums should be added to the above balance sheet on both sides.

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BALANCE-SHEET No. 3.

REVENUE ACCOUNT.—ESTIMATED REVENUE AND EXPENDITURE OF THE PORT AUTHORITY, WITH THE RIVER CLOSED BY A BARRAGE AT GRAVESEND.

Revenue.	£	*Expenditure.*	£
Existing Revenues of the Thames Conservancy Board	101,234	Administration Officials, offices, legal and other statutory duties ..	42,918
Existing Revenues of Trinity House Existing Revenues of the Watermen's Company .. .. Present Revenues to be discontinued and charges for licenses, &c., made by the Port Authority, for lighting, buoying, &c., estimated at (not including Pilotage)	40,000	Liabilities on Capital Account taken over from the Thames Conservancy Board— £ Interest on Loans .. 3,109 Sinking Fund 1,026	4,135
Sale of water for Industrial and other purposes	45,000	Increased Fees to Members (40 at £200)	8,000
Tolls for use of Tunnel for Railway Companies	30,000	Estimated cost of working Sluices, &c., and Towage	9,800
Tolls on all Vessels passing through the Locks at Gravesend, estimated at 31,000,000 tons at ¾d.	95,319	Maintenance and Repairs of Barrage and Works	3,500
		Interest at 2¾ per cent. on Capital, £5,250,000	144,375
		Sinking Fund, 1¼ per cent. on Capital, £5,250,000	65,625
		Cost of pumping drainage, estimated by Mr. Hennell .. .. .. Maintenance and Repair of Pumping Plant	33,200
(*see* p. 164.)	£311,553		£311,553

NOTES ON COMPARATIVE BALANCE-SHEETS.

It has been assumed in Balance-sheets 2 and 3 that the existing administrative expenditure of the Thames Conservancy Board will suffice for the expenses of the Port Trust or Harbour Board. This is, perhaps, an optimistic view, as similar amalgamations have rarely borne out such estimates.

It has also been assumed that (in No. 2) the administrative cost of managing the docks after purchase will be covered by the charges and not increase the general management expenses of the Port Trust. This, also, is undoubtedly an optimistic view, as there is no doubt that these expenses under the Port Trust will be greater than under the present economical management of the Dock Companies, who are governed by the necessity of making dividends, and are better acquainted with the dock business than any river Authority can become.

BALANCE-SHEET No. 1 sets out in simple figures the revenue and expenditure of the existing Authorities controlling the river, who thus draw annually the sum of £296,877 from the shipping trades and expend £238,281 of this sum on the Port, the balance of £58,596 being expended elsewhere.

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BALANCE-SHEET No. 2 is an estimate of the income and expenditure of a Port Trust constituted as recommended by the Port of London Commission, after purchasing the docks and dredging the river, and shows that a deficit of £700,701 per annum will have to be provided for by increased dues levied, probably (as recommended by the Port of London Commission) on the goods, as distinct from the shipping. This additional charge is equal to a levy of 10d. per ton on the shipping entering the Port.

BALANCE-SHEET No. 3 is an estimate on similar lines of the revenue and expenditure of a Harbour Board or Port Trust, after closing the river by a Barrage and Locks at Gravesend. In this account the expenditure is balanced by the revenue. If the Dock Waters are purchased the annual charge must be added to both sides of this account.

TOTAL EXPENDITURE IN THE PORT OF LONDON.

A true comparison of the above balance-sheets can, however, only be arrived at after taking into consideration the whole of the charges and dues levied on the trade of the Port under each set of circumstances. These further charges include :—

(1.) The Dock charges.
(2.) The Wharfingers' charges.
(3.) The Barging and Towing charges.
(4.) Labour.
(5.) Pilotage.

(1.) The *Dock Charges.*—It has been seen above (p. 154) that these amount to £2,311,302 per annum.

(2.) The *Wharfingers' Charges* are not recorded in exact figures, but there is the statement of Mr. J. I. Rogers, in the Port of London Report, on p. 61, that the wharfingers' charges amount to about 10 per cent. less than those of the docks; so that as the tonnage entering the docks in 1903 was 7,954,887, and the tonnage discharged in the river was 8,842,147, which went to the wharves and factories, if we take this proportion at the rate of $\frac{9}{10}$ths of that imposed in the docks, we get a total sum levied by the wharves of £2,310,000 on the river-discharged shipping, these charges in both cases including exports.*

(3.) The *Barging Charges* cannot be exactly determined, but a near approximation can be made thus :—The tonnage of goods discharged by barge and that carried from wharf to wharf, &c., may be taken as equal to the registered tonnage of vessels discharged in the river—viz., 8,842,147, and 75 per cent. of the tonnage of the docks, say, 6,000,000, and the average rate per ton at 1d. per mile, or (as the mileage might be averaged at 4 miles) 4d. per registered ton; total, £221,053 per annum, which is probably below the truth.

Towage applies to about two-thirds of the barge traffic and probably one-eighth of the shipping, both entering and clearing under present conditions.

In connection with Balance-sheet No. 2, owing to the greater depth of the river and strength of current, and to the increased size of ships likely to use the Port, towage and pilotage may be expected to increase.

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* *See* footnote, p. 159.

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But in the case of No. 3, the absence of current, freedom of navigation, and permanent high water will tend to reduce towage. On the other hand, the absence of tide currents will lead to more universal towage of barges, while the present services of tugs at dock entrances will be chiefly transferred to the locks at Gravesend. It is impossible to estimate these factors with any approach to accuracy, and they may be left out of the account. The probabilities point to an increase of towage, set off by saving of time and of delay.

(4.) *Labour expenses* apply principally to ships discharging in the river. In the docks and at the wharves the labour is partly supplied by the dock and wharf owners. Some shipowners, however, make special terms with the dock companies, and discharge or load at their own cost, renting also quay or warehouse space. In the river the bargemen do part of the work, the ship's crew with the help of some casual labour the rest. But as it is difficult to arrive at any definite sum as the annual cost of labour by either a Port Trust or a Barrage it may be omitted from the estimates.

(5.) *Pilotage* can be estimated from the returns of the Trinity House for pilotage above Gravesend, and will require to be added to balance-sheets Nos. 1 and 2. But as to No. 3, with a Barrage there will undoubtedly be a reduction in the pilotage, because many vessels will be able to navigate the river quite safely without a pilot, owing to depth of water and absence of current, and the sum expended in pilotage may be reduced by at least 50 per cent., or, in round figures, £70,000. Compulsory pilotage—which was generally condemned by the witnesses on the Port of London Commission—will, no doubt, be abolished.

We can now compare the results of the three cases investigated financially in the following summaries of total expenditure on all counts except labour in the Port of London under these three sets of conditions.

(1.) TOTAL EXPENDITURE IN THE PORT OF LONDON (OMITTING LABOUR AND TOWAGE) UNDER PRESENT CONDITIONS.

	£	s.	d.
Total revenue of the river Authorities from Balance-sheet No. 1, including pilotage	296,877	0	0
Dock Companies' charges	2,311,302	0	0
Charges on Goods discharged in River	2,310,000	0	0
Barging	221,053	0	0
	£5,139,232	0	0

(2.) TOTAL EXPENDITURE IN THE PORT OF LONDON WITH A DREDGED RIVER AND A PORT TRUST OWNING THE DOCKS.

	£	s.	d.
Total revenue of the Port Trust from Balance-sheet No. 2 ..	841,935	0	0
Dock Companies' charges	2,311,302	0	0
Charges on Goods discharged in River	2,310,000	0	0
Barging	221,053	0	0
Pilotage	146,066	0	0
	£5,830,356	0	0

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(3.) Total Expenditure in the Port of London with a Barrage at Gravesend.

	£	s.	d.
Total revenue of the Harbour Board from Balance-sheet No. 3.	311,553	0	0
Dock Companies' Charges reduced 10 per cent. to agree with the Wharfingers' charges	2,080,172	0	0
*Charges on Goods discharged in the River	2,310,000	0	0
Barging	221,053	0	0
Pilotage	70,000	0	0
	£4,992,778	0	0

From the foregoing abstracts of expenditure in the Port of London, under the two sets of conditions as a tidal or a non-tidal port, we can compare their respective financial advantages.

(1.) The tidal port now costs £5,139,232, which is equal to a tonnage charge of 3s. 5d. per registered ton on all the goods.

(2.) The tidal port under a Port Trust will cost £5,830,356 per annum, which is equal to a tonnage charge of 3s. 11d. per registered ton on all goods entered and cleared.

(3.) The non-tidal port will cost £4,992,778 per annum, equal to a tonnage charge of 3s. 4d. per registered ton on all the goods entered and cleared.

The difference (£837,578) between Nos. 2 and 3 is a very substantial saving, which must powerfully affect the course of future trade, in which all interests will benefit.

But the savings effected, as set out in figures, will be considerably augmented by the general saving of time in all the operations of the Port, from the entry of a vessel at Gravesend to its departure from the Barrage, including time of barges, tugs, labour, &c., which must amount to a very large sum annually, when it is remembered that the usual demurrage charge on steamships (as stated by Mr. Anderson, Port of London Commission, p. 98) is 4d. per registered ton per day, which for a vessel of 3,000 tons is equal to £50 per day, which is evidently much below the actual loss. The loss on barges, idling and waiting, through tidal causes must represent at least one-third of their earnings, besides loss of interest on capital lying idle.

The total of these unascertained savings must amount to several hundred thousand pounds per annum on the most conservative estimate.

But perhaps the most important financial result in the end will be the removal from the financial horizon of enormous prospective expenditure constantly held up before the public on a new water supply for London (for the Barrage will enable a practically unlimited supply to be drawn from the river, now necessarily limited by the need for tidal cleansing, as described on p. 28), estimated at £24,000,000; the dredging of the river and improvement of the docks, estimated at £7,000,000; and the purchase of the docks, estimated at £30,000,000; none of which will be either necessary or advisable.

* These figures are necessarily approximate, about 75 % of the goods entering the docks are barged into the river, and of these probably 500,000 tons go to the Waterside Manufacturers, the remainder being chiefly landed at the wharves. But of the river-discharged goods some proportion is barged into dock, and from 7 to 8 million tons go to the Waterside Manufacturers, who, of course, levy no charges. No returns are available on these points, but as the same totals appear in each balance sheet accuracy is not essential for comparison.

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SECTION XXIV.

THE FUTURE OF THE DOCKS AND WHARVES.

The effect upon shipping interests and their accommodation of the construction of a Barrage at Gravesend, has been subject of much misapprehension. The changes that must necessarily result have not been forecast with any evidence of either ability or care. Those who have championed the dock companies, and who might be expected to know something of the river and the conditions necessary for its improvement, have exhibited a lamentable want of technical knowledge, grossly magnifying a number of inaccurate statements as a basis for their objections.

Proposed Dock Purchase and its Cost.

It is most unfortunate for the settlement of any course of action for the improvement of the Port that the Royal Commission recommended the purchase of the docks as part of their scheme, as this proposal has proved to be an insurmountable obstacle to a settlement. The past history of the dock companies has not been of a triumphant character financially—it is not necessary here to go into the reasons for this, which may be found fully set forth in the Report of the Royal Commission on the Port of London, 1902—and the result of such official recommendation under such circumstances has, of course, been that extraordinary efforts have been made to bring about the suggested unloading of the shareholders' interests on to the broader shoulders of the British taxpayer, especially as the future of the companies' undertakings does not forecast any evidences of improvement. There is no reason to suppose that the dock companies do not understand their business, nor is it to be expected that the ratepayers can do it more efficiently by means of a "Trust." The deficiencies of the dock companies are distinctly the result of want of means, to which cause is traceable the lack of modern appliances and improvements so much complained of (*see* forward, p. 165), and which always operates to retard any business undertaking and keep it behind the times. This is substantially the chief complaint brought against the dock companies.

It is a common idea when any undertaking appears to fall behind that a change of management should take place; but no such change can alter the difficulties in the river itself, outside the docks, or improve the navigation, or avoid many other of the disabilities from which the trade and the docks now suffer. And assuming that the proposed Port Trust does, in fact, purchase the docks, take over their management, and bring them up to date, it is manifest that, apart from costly management—or mis-management—likely to follow, money will have to be found to put the docks on a modern footing (estimated by the Port of London Commission at £4,500,000), dredge the undredgable river at the estimated cost of £2,500,000 (Sir A. Binnie), and pay compensations for damage to riverside properties, besides a heavy annual expenditure for continuous dredging to keep the channel open.

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It is evident that the interest and sinking fund for these heavy outlays must fall on the merchandise in the ultimate, as it invariably does, and thus increase considerably the dues and expenses of the Port, without any corresponding relief or reduction of working expenses or even saving of time.

To all this must be added the annual increase in the guaranteed interest on the dock stock taken over above that now earned, the total capital being in round figures £24,500,000, and the total net profit for 1901, £732,856—equal to a general dividend of 3¾ per cent.; but the price that will be awarded may be expected to be about 30 millions, reducing the available dividend to 2⅝ per cent., on which at least 3¾ per cent. will have to be guaranteed, the loss thus amounting to £90,000, to which a sinking fund of about 1¼ per cent. will have to be added (the docks have now no sinking fund) or £372,500, making £462,500 of additional revenue to be provided out of dues and charges.

But the dock charges are already subject of much complaint as being too high all round, and have the further unsatisfactory result of keeping up those of the wharfingers who regulate their charges by those of the docks.

It is alleged that the charges of the public wharfingers are based upon those of the dock companies, with a deduction, and that in many cases there is a working agreement or understanding between the companies and the wharfingers, so that the merchant who takes his goods through the wharfingers pays a little less than if he had taken them through the docks.—(Port of London Commission Report, p. 90.

These additional revenues are equal to about a 60 per cent. addition to the present profits of the docks, or 4s. 9d. per ton of goods landed in the docks.

But the capital outlay is further increased by the £4,500,000 recommended by the Royal Commission for dock extensions and improvements and £2,500,000 for dredging, the interest upon which at 2¾ per cent. equals £192,500 per annum, only a small part of which sum can be considered as remunerative, that is, productive of added revenue in increased tonnage of shipping, the remainder being expenditure necessary to retain existing business.

The net result, therefore, neglecting the inevitable rise of wharfage rates, must be a severe additional burden on the goods and shipping charges, with little or no increase of facilities or removal of grievances.

The Port Trust as Trader.

As to the question of the desirability of a Port Trust entering into competitive trading with the extensive wharf interest, but little need be said. In doing so it would have to depart seriously from the law of unpreferential treatment which is the foundation of the harbour systems all round the coast, the spirit of which governs all public bodies, and it is difficult to see how, with the docks on its hands and their annual interest to meet, fair treatment could be meted out to the riverside traders and the shipping companies. Any loss on the docks will, if not made up by increased charges on goods, presumably be paid by the City or Council rates—that is, by the buyers of the goods.

The offer to purchase the docks has, of course, been followed by a demand to purchase the wharves too, in justice to all parties. Their capital value is about

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£13,141,233, and profit income estimated at £657,061; so that we should have a Port Trust with a capital of :—

	£ s. d.
Dock purchase	.. 30,000,000 0 0
Dock improvements and dredging	.. 7,000,000 0 0
Wharf purchase (about)	.. 18,000,000 0 0
TOTAL	£55,000,000 0 0

Such a proposal ensures its own rejection. The people of London have been recently saddled with one such gigantic combine which has produced no relief, and are not likely to adopt another.

THE FUTURE OF THE DOCKS.

But assuming that the Barrage is constructed, in what way and to what extent will the docks be affected, presuming there is no purchase ?

Important and far-reaching changes will certainly result in working and management. All the basins directly connected with the river can be thrown open as public waters, the dock gates kept open or removed, and possibly the entrances widened.

This will effect at once some important reductions in expenses of working.

The working of lock gates, pumping lockage water, &c., now costs the companies £70,000, which can all be saved.

Mudding the docks is another costly item, due to the depositing of river mud in the basins (*see* p. 36), which also will be wholly saved. The cost in 1899 was £40,000.

But perhaps the trouble with the barges and the "free-water" law has been the most detrimental drawback in the dock companies' business. About 213,000 barges and lighters enter and leave the docks annually without payment, the cost to the companies being not only that of locking in and out and consequent pumping, but the assistance rendered the barges free, and the extent to which their presence hampers and delays work in the docks. The cost of this to the companies was estimated by Mr. Baggallay (Engineer to the London and India Dock Company) at £50,000 per annum.

The removal of this "free-water" difficulty, and the quarrel it has kept up between the docks and the barges, ought in itself to be a very high recommendation of the scheme to the dock companies. They have agitated for many years for the removal of this grievance without avail.

The principal question, however, is—will the shipping continue to use the docks as heretofore under the new conditions ?

The shipowner's chief demands are :—A berth easily reached, with sufficient depth of water to prevent grounding, rapid despatch, and low charges. Given these, he will as soon go into dock as lay outside at a wharf.

The question then arises : Have the docks better accommodation and facilities for quick despatch, &c., than the wharves ? In many ways they certainly have. With free, open entrances, ships will be able to berth at any hour, with ample depth of water. At the wharves only shallow draught vessels, of moderate length, will be able to do this. Then at the docks the cargo can be put direct into trucks. This the wharves cannot do.

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There only remains to consider the comparative charges ; and, taking into account the savings effected and the reduction of capital which will be represented by the public acquisiton of the water areas of the docks, the companies ought to be able to very materially reduce their charges and compete successfully with their outside competitors and pay better dividends.

Their fear is that the dockisation of the river will result in a great extension of wharves down river.

This is a most unlikely contingency, for the following reasons :—

Such wharves will be too far from the markets and merchants and without rail connection, having too shallow water in front for large vessels to lie without grounding, and will be costly in barging or cartage and towage.

Such wharves will not pay to construct unless the existing accommodation is found insufficient. But with high water all day and night the working capacity of the existing wharves will be almost doubled, because the working hours will be greatly extended.

Further than this, the dock companies' St. Katharine's and London Docks—now almost abandoned—can again be rendered serviceable with open entrances. These entrances will probably require widening and perhaps deepening also, although there will be about 23 feet of water always available, so that all but the largest class of vessels can be accommodated, and it will be no more difficult to reach and enter these docks than any other berthage in the river and at all hours. These docks have the great advantage also of being close to the markets and merchants' offices, and are very suitable for produce, fruit and mixed cargoes, but will require modern improvements and appliances.

The improved navigation and great depth always available will enable large vessels to use the West and East India Docks also, whose trade has been diminishing from insufficient depth in the river and difficulty of navigation.

Mr. Baggallay, Engineer to the London and India Docks Company, said (Port of London Report, p. 67) :—" With regard to both the West India Docks and the Albert Docks, it is in depth only that ships are beginning to outgrow them, and this can be remedied should improvements in the river enable deeper vessels to navigate the river to them."

The Chairman of the London and India Docks Company also said that " only the smaller ships care to run the risk of navigation in the upper (tidal) river." These risks are entirely tidal, and with a dockised river will be obviated. It will be as safe to navigate a large vessel in the upper reaches as in the lower, in the absence of tide currents.

Considering that about 75 per cent. of the cargoes brought into dock by the ships is discharged into lighters and goes out into the river, and about 80 per cent. of that which is loaded into ships in dock is brought in by lighters, it is clear that a free entrance open at all hours must greatly facilitate this business to the advantage of the dock companies, and, by relieving the companies of the cost of locking and assistance to the barges, save them the greater part of the £50,000 they assert as the

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cost of it (this sum only applies to the London and India Docks); so that we shall be justified in crediting a saving of £40,000 per annum, and we get as the summary of direct money-saving to the companies the following :—

	Per Annum. £	s.	d.
Saving in working entrances and pumping	70,000	0	0
„ in mudding	40,000	0	0
„ in barge work	40,000	0	0
TOTAL	£150,000	0	0

It is also suggested to take over the dock water areas and open them to the river as public waters; and that either a capital sum be paid for them, or an annual payment to cover interest on the capital which they represent. This will relieve the companies of a large part of their burden of unremunerative capital, so that the savings effected above will be of much greater value to them than if spread over their present capital stock. Such amount must be added to the balance sheet, p. 156.

COMPLAINTS AGAINST THE DOCK COMPANIES.

A considerable part of the Report of the Royal Commission on the Port of London, 1902, is occupied with these complaints, which emanate from shipowners, merchants, and barge-owners. A few extracts from these will show the nature and extent of them, and indicate the directions in which amendment is necessary in their appliances and methods of business.

Page 86. (201.) The complaints of the shipowners may be summed up under the following heads :—

(1.) The inadequacy of the existing quay and berth accommodation for ships, and, in some cases, of entrance locks and depth of water in the docks, to meet the increased and increasing dimensions of modern steamships. They think that, in the words of Sir Edwyn Dawes, there should be "another large and commodious deep water dock, provided with all modern appliances for rapid discharging and loading."

(2.) The inadequacy of the existing quay space and sorting sheds to receive the increasing bulk of modern cargoes, and to give facilities for their rapid sorting and delivery. It is urged that there is special need for accommodation for refrigerated produce, a new and large branch of trade.

(3.) The want of easy access to the quays or barges, resulting in delays in the clearing of cargoes.

(4.) The consequent congestion of the docks, caused by barges floating about while they await means to approach, and getting in the way of the movement of ships.

(5.) The insufficiency of graving docks, and the inadequacy of dock plant, of cranes, tugs, &c.

COMPLAINTS OF SHIPOWNERS WITH REGARD TO THE DOCKS.

Page 95. (200.) Sir Edwyn Dawes (British India Steamship Company) said, speaking for shipowners :—"It is despatch more than anything else that we want, owing to the increasing value of the ships we employ. The view that despatch in loading and discharging cargo is even more important than low port charges was supported by Sir Thomas Sutherland, M.P., the Chairman of the Peninsular and Oriental Company, and by other representatives of ship-owning companies who appeared before us. Not only does the greatly increased capital value of modern ships make it necessary that they should earn profits without waste of time, but the punctuality to dates due to the use of steam power makes it most important that the time of vessels competing

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for trade with other home and foreign lines should be calculated with a near approach to certainty. The main complaint of large shipowners with regard to the Port of London is that such despatch and punctuality are not easy to reckon on. This is due to the state of the river channel, which we have previously dealt with, and also to the conditions prevailing in the docks."

(206.) It was stated by other witnesses that, when the docks are full of shipping, as soon as one vessel has cleared another comes in to take the vacant berth. The lighters waiting to come alongside the quay to take the cargo of the first vessel then have to wait till its successor has also discharged her cargo. As one witness said, speaking of the Albert Dock:—"When there is a large ship discharging, there is no berth for the barge to load in; she may poke her head in, but she cannot get to do very much until the ship is discharged. Then another ship comes alongside, and there again you have to wait for your goods." Meanwhile the quay and sheds become blocked with two or more barges, and the difficulty of sorting is increased. At the same time, it was alleged, a fleet of barges, insufficiently manned, are floating obstructively about the docks, while consignees have to pay their owners for the hours or days thus idly spent, and have, moreover, the vexation of not being able to reckon with any certainty upon the arrival of goods at their warehouses.

G. E. BRIGHTMAN.

Page 103. "At the Surrey Docks, owing to their crowded state, boats to the number of 12 or 15 at a time, sometimes more, were waiting at Gravesend to get in the Surrey Docks, and when they got in they too often had to wait days before a start was made." Times of discharging, 16 to 23½ days.

Page 104. "I have found the other ports in the United Kingdom quicker, excepting Liverpool." "A great deal of the detention is owing to going into barges."

Mr. SCRUTTON.

Page 597. "So far as I have been able to trace, not a single ship-owner has come forward to express satisfaction with the management of the docks."

Sir T. SUTHERLAND.

"We feel strongly under the present port system that ship-owners are not on solid ground. at all, but are very liable to have their business further interfered with in the interests of the dock shareholders, and without increased efficiency or advantage to the shipping world."

"If you walk through the docks and see the state of their quays, and if you look at their tugs—which are pretty well coeval with Noah's Ark, I think—and their appliances in general, you will see that the expenditure is kept down to its lowest possible point, and one that I should myself say is hardly compatible with efficiency."

A. L. JONES.

"The inability to dock vessels (Millwall Dock) drawing, say, 25-26 feet of water, except at top spring tides, is a very serious matter. The steamers have either to wait at Gravesend until there is sufficient water or to lighten. Both operations are very expensive. At neap tides it is only possible for steamers drawing about 20 feet to dock."

"In Avonmouth or Liverpool we should discharge about 3,500 tons a day, in London we should discharge about 500 or 600 tons a day—three days as against 14."

COMPLAINTS OF TRADESMEN AS TO DOCK CHARGES ARE THUS REFERRED TO.

Page 89. (213.) Mr. J. I. ROGERS maintained that "the root idea of the dock arrangements in London is that goods have to be landed in a public warehouse and housed there. With this view a consolidated rate is charged, which most goods have to pay directly they are landed on the quays." And he alleged that "this consolidated rate includes a number of services which are not required in a vast number of instances." Mr. SMITH, in the dried fruit trade, said that "for goods that are taken away from the dock quay as quickly as possible the dock charges are on the same scale as if the goods were warehoused." "In London," said Mr. TASKER, of the flour trade, "you pay the quay rate and get nothing for it; you simply have to wait, get your flour when they please

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to let you have it; and if you want it weighed, sorted, classified, &c., you have to pay the full landing, storage, and delivery rates."

It was alleged by a witness in the paper trade that "except for very small parcels the dock company's rates are prohibitive."

Complaints that their trades were adversely affected by system of charges were also made by representatives of the trades in wool, jute, timber, grain, and flour, leather and hides, wines and spirits, cotton, coffee, and other commodities.

Dock Companies' Complaints.

Besides the greater question of the "free water" difficulty referred to above, the dock companies would not admit that there was a sufficient ground for complaints; but, while refusing to admit that there was any dereliction on their part, they had their own grievances to complain of, the principal of which were the crowding in dock of barges and the cost of locking them in and out, the loss of business from goods delivered overside into barges to be landed outside the docks, insufficient depth of water opposite their entrances, cost of mudding the docks due to foul river water, and so on.

C. J. C. Scott.

Page 292. "The total tonnage of the ships and steamers entering the dock with cargoes is little more than one-half of the estimated total tonnage of the lighters and barges that enter the docks in the course of the year."

"Practically, all these barges have to be worked in and out, and proportionately to their tonnage involve the docks in at least as much expense for locking as ships for which a special charge of 3d. for locking and interlocking is made."

Page 293. "The barges are taking away from the (dock) companies in ever-increasing quantities the goods for whose reception they were originally designed."

Page 294. "We estimate that for every £1 that we have to spend in pumping water into the docks to make good this waste (locking water) we have to spend £4 in removing the mud deposit."

"The services which the docks have to render to the barges are enormously in excess of anything they have any legal right to ask."

The Wharfingers also point out that the docks possess advantages which they do not share:—

H. C. Smith.

Page 120. "There are a great many ships which cannot come up the water towards London Bridge, and a great many will not come up the river; they will not lie aground; there are few wharves—only two or three—where ships of any great draught of water can lie afloat at low water."

H. T. Moon.

Page 131. "There are advantages in the docks in the matter of loading, due to the water remaining at one level.

G. Coombe.

Page 134. "The delay in getting our goods is on the increase, due to the time it takes to get the goods collected at the docks."

Further, that the shallowness of the river fronting their wharves necessitated vessels grounding, and precluded the business of the larger class of steamers, thus operating very unfavourably against the wharves.

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The direct advantage, therefore, to the wharfingers and riverside manufacturers of a Barrage and consequent high water are :—

Continuous high water, always at one depth, enabling their quays to be approachable at all hours, so that ships and barges can be continuously discharged or loaded. Such work, in emergency, can be extended to 24 hours per day, or it may be found profitable to work day and night shifts to shorten ships' time in port. It is obvious that with this advantage delays will be very largely reduced and a much greater volume of business can be done in the working day. There will be more regular employment for men and machinery without increase of capital.

Ships and craft can be more easily moored in still water than in a tideway, and remain at one level for loading or discharging.

THE SOURCES OF ECONOMY, therefore, to which future legislation must be directed are :—Reduction of the expenses incurred in the handling of cargo, more rapid handling, greater despatch in berthing, navigating, clearing, loading, and discharging vessels, reduction of dues and costs of collection, quicker and cheaper distribution and collection of goods as between ship and market or consignee, simplification of all routine business. These are the reforms that have been persistently demanded on all hands, and which the vast population of London is entitled to expect as a result of whatever changes are introduced in the management and working of the Port of London.

As against the introduction of these reforms there is probably no other port in the world in which conflicting interests, opinions, and ancient usages are so deeply rooted, or where such enormous lethargy and inertia obstruct every attempt at reform. Ponderosity characterises every movement and administration ; old charters, privileges, customs, and usages cling like bunches of barnacles to every vessel of progress, and it will require a very masterful mind and arm to make any useful advancement. Every interest cries out against its own reform, and one and all seem to act as though the River Thames and the vast population bordering it was their own particular and vested interest.

Unable hitherto to combine for their own regeneration, they have complained of being put to expense in objecting and resisting the efforts of Parliament to introduce changes. Each apparently wants all the others to reform, but will not initiate its own amendment. The river authorities naturally do not favour their own extinction or even re-construction. It would seem that another Commission will be needed to bring about a scheme of administration, the proposal most in evidence now being the constitution of a Harbour Trust on the lines of the Mersey or Glasgow Boards as a first instalment, the improvement of the river and other matters to be left to its future consideration.

Such a Board could, and probably would, introduce many economies into the administration by abolishing unnecessary forms and restrictions and reducing cost of control ; but too much reliance must not be put on reducing expenses by concentration—the main sources of future savings are to be found, as indicated above, in the improvement of the river itself, and no time ought to be lost in determining this main factor apart from mere change of administration.

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APPENDIX.

BILL PROPOSED BY THE THAMES BARRAGE COMMITTEE, SESSION 1906.

THAMES HARBOUR.

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A BILL FOR THE INCORPORATION OF COMMISSIONERS AND EMPOWERING THEM TO CONSTRUCT A HARBOUR AND WORKS IN AND TO IMPROVE THE NAVIGATION OF THE RIVER THAMES; AND FOR OTHER PURPOSES.

Preamble.

WHEREAS the navigation of the River Thames is year by year becoming more difficult and dangerous and the extensive and important trade of the river is in danger of being injured and retarded by lack of proper facilities for vessels trading in and from the river;

And Whereas the more effectually providing for increased depth of water in the navigable part of the River Thames and its estuary has been for many years urgently demanded by the traders shipowners and other persons who use and navigate the river;

And Whereas Her late Majesty Queen Victoria did by her Royal Warrant dated the 21st day of June 1900 appoint her Royal Commission to inquire into the administration of the Port of London and the water approaches thereto the adequacy of the accommodation provided for vessels and the loading and unloading thereof the system of charge for such accommodation and the arrangements for warehousing dutiable goods and to report whether any change or improvement in regard to any of the above matters was necessary for the promotion of the trade of the port and the public interest;

And Whereas the said Royal Commission was revoked and a new Commission appointed by Royal Warrant by His Majesty King Edward the Seventh dated the 6th day of March 1901 and the said Commission reported to Parliament upon the 16th day of June 1902;

And Whereas in the said Report of the Royal Commission on the Port of London the Commissioners recommended among other things the desirability of deepening the navigable River Thames up to London the creation of a single Authority to control the said port the transfer to the said single Authority of powers now exercised in the said river by several Authorities and the raising of sufficient loans for the works deemed necessary for the improvement of the Port of London and Thames Estuary;

And Whereas to give effect to the foregoing purposes and recommendations it is expedient that a body of Commissioners representative of all the public and trading interests in the River Thames should be incorporated and powers conferred upon them as provided by this Act;

And Whereas it is expedient in order to effect the purposes of this Act that the level of the water in the Thames from Teddington Weir to Gravesend should be maintained at or about Trinity high water level and that the Commissioners be empowered to construct a dam with sluices locks and weirs across the river at Gravesend with the other necessary works as in this Act provided;

And Whereas it is expedient that the Commissioners should be empowered to purchase compulsorily or by agreement such of the lands shewn on the plans deposited as hereinafter mentioned as they may require for the construction of the said works and approaches thereto and that they may also acquire by agreement any other lands or buildings bordering upon or near the tidal area as hereinafter defined for purposes necessary to give effect to the provisions of this Act and sell or lease the same;

And Whereas it is expedient that the other powers contained in this Act should be conferred upon the Commissioners for more effectively carrying into execution the purposes of this Act;

And Whereas plans and sections shewing the lines and levels of the works authorised by this Act and also a book of reference to such plans containing the names of the owners or reputed owners lessees or reputed lessees and of the occupiers of the lands required

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or which may be taken compulsorily for the purposes or under the powers of this Act were duly deposited with the Clerks of the Peace for the Counties of Essex and Kent and are in this Act referred to as "the deposited plans sections and book of reference";

And Whereas the objects of this Act cannot be effected without the authority of Parliament;

MAY IT THEREFORE PLEASE YOUR MAJESTY

that it may be enacted and be it enacted by the King's Most Excellent Majesty by and with the advice and consent of the Lords Spiritual and Temporal and the Commons in this present Parliament assembled and by the authority of the same as follows:—

1. This Act may be cited as "The Thames Harbour Act 1906." Short Title.

PRELIMINARY.

2. In this Act the several words and expressions to which meanings are assigned by the Acts wholly or partially incorporated herewith have the same respective meanings unless there be something in the subject or context repugnant to such construction and in this Act:— Interpretation.

The expression "the Commission" means the Commission by this Act incorporated and the expression "the Commissioners" means the Commissioners for the time being empowered to carry into effect the provisions of this Act.

The expression "the tidal area" means the Thames as defined in Section 3 of the Thames Conservancy Act 1894 substituting for "from the entrance to Yantlet Creek in the County of Kent to the City stone opposite to Canvey Island in the County of Essex," the words "from Warden Point in the County of Kent to the entrance of Havengore Creek in the County of Essex," and extending up to Teddington Weir but no further.

The expression "the Thames Harbour" means that portion of the "tidal area" from Teddington Weir down to and including the dam at Gravesend and within the jurisdiction of the Commissioners.

The expression "the River" means the River Thames between Teddington and Gravesend.

The expression "the Corporation" means the Corporation of the City of London.

The expression "the Conservancy" means the Thames Conservancy Board.

The expression "the Trinity House" means the Corporation of the Trinity House of Deptford Strond.

The expression "the Watermen's Company" means the Master Wardens and Commonalty of Watermen and Lightermen of the River Thames.

The expression "the Estuary" means the Thames Estuary from the Dam to be constructed at Gravesend to the North Foreland.

The expression "the Clerk" means the Clerk for the time being to the Commissioners.

The appointed day shall be the first day of September 1906 or such other later day as the Board of Trade may appoint and different days may be appointed by the said Board for different purposes and for the different provisions of this Act.

3. The following Acts and parts of Acts are (except where expressly varied by this Act) incorporated with and form part of this Act (that is to say):— Incorporation of Acts.

The Land Clauses Acts;

The Harbours Docks and Piers Clauses Act 1847 (except sections 16 17 59 60 66 to 68 (both inclusive) 77 78 101 and 102) and the expressions "the Undertakers" and "the harbour dock or pier" in that Act shall mean respectively for the purposes of this Act the Commissioners and the Thames Harbour;

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The Commissioners Clauses Act 1847 except the clauses with respect to the election and rotation of the Commissioners.

APPOINTMENT OF COMMISSIONERS, ETC.

Repeal of Acts.

4. As and from the appointed day the Watermen's and Lightermen's Amendment Act 1859 and any Act or Acts amending the same shall be and the same are hereby repealed.

Incorporation of Commissioners.

5. The Commissioners named in and appointed under the provisions of this Act and their successors from time to time chosen and acting in pursuance of this Act shall be one body corporate by the name and style of "The Thames Harbour Commission" and by that name shall have perpetual succession and a common seal with power to purchase take hold use and dispose of lands and other property for the purposes of but subject to the provisions of this Act.

First Commissioners.

6. Sir Thomas Brooke-Hitching, Colonel Samuel Bourne Bevington, V.D., Richard Stapley, Arnold Frank Hills, Charles Cobham, David Urquhart and twelve others to be nominated by them or the majority of them and consenting to such nomination shall be the First Commissioners and shall continue in office until the appointed day.

Appointment and Election of Commissioners.

7. From and after the appointed day the number of Commissioners shall be thirty-seven and the Commissioners shall be appointed or elected as follows:—

There shall be appointed in manner hereinafter provided—

By the London County Council	4
By the Corporation	4
By the Admiralty	1
By the Board of Trade	1
By the Trinity House	1
By the Metropolitan Water Board	1
By the County Council of Essex	1
By the County Council of Kent	1
By the County Council of Middlesex	1
By the County Council of Surrey	1
By Dock Companies	3
By the Thames Conservancy	1
By Railway Companies	2
By the London Chamber of Commerce	1
By the London Chamber of Shipping	1
	24

There shall be elected in manner hereinafter provided—

By owners of ships trading to and from the Thames Harbour ..	6
By waterside manufacturers	2
By wharfingers	3
By owners of river craft	2
	13

There shall be paid to the chairman and vice-chairman or either of them such salaries or salary as the Commission may determine.

Provided that subject to the provisions of this Act the Board of Trade shall have power to make regulations with respect to the proceedings of the Commission and the appointment and election of the Commissioners.

Mode of Nomination.

8. The persons nominated under the last preceding Section shall be nominated at a meeting of their respective Boards of which meeting and of the business to be

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transacted thereat due notice shall have been previously given by the Secretary or other official to whom this duty shall properly belong such meeting to be held any time previous to the first Thursday in September in each year and the persons to be nominated shall be elected by a majority of the Board then present and the said persons shall then and there be provided with an official certificate of their election and the same be duly notified in writing to the Commissioners.

Provided that—

(1) The persons nominated to represent the Docks Companies shall be nominated at a joint meeting of directors delegated from the following Companies viz.—The London and India Docks Company The Surrey Commercial Dock Company and the Millwall Dock Company such meeting shall be held before the month of September in each year such delegates to be provided with copies of the resolution of the meeting at which they were empowered to act such copies to be signed by the chairman of each such meeting and the number of such delegates so authorised by each company shall be in the proportion of one delegate for each million or part of a million sterling subscribed capital owned by such company in the form of stock shares or debentures. At the joint meeting of delegates the person or persons to be nominated shall be elected from the delegates present by ballot and the result of the election shall be duly notified in writing and signed by the chairman and transmitted to the Commissioners.

(2) The appointment of the Commissioners to be nominated by the Railway Companies shall be made through the Railway Companies' Association at a meeting of such Association to be held prior to the month of September in each year so long as that association continues to exist and thereafter by such companies and in such manner as the Board of Trade may by order direct.

Mode of Election of Elected Members and Qualification.

9. With regard to the election of elected members as provided by the Section of this Act whereof the marginal note is " Appointment and Election of Commissioners " the following regulations shall apply :—

(1) Any person to be so elected shall be a person engaged in the particular industry he is chosen to represent and shall possess the following qualifications :—

(*a*) The ownership of property to the value of one thousand pounds whether such property be floating or fixed employed in the particular industry which he represents.

(*b*) He shall have been engaged in the said industry for not less than ten years and shall be not less than thirty years of age.

(2) The election of persons to represent each industry shall be conducted as provided in Sections 6 to 35 of the Commissioners Clauses Act 1847 omitting Sections 17 and 20 and the qualifications of voters shall be :—

(*a*) The ownership or occupation of property rated to the poor and employed in the particular industry for which the vote is given to the amounts and according to the scale set out in Section 24 of the Commissioners Clauses Act 1847 provided that no person shall be qualified to vote unless the property in respect of which he claims to be entitled to vote be of the rateable value of at least £25.

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(*b*) The ownership of property not rated to the poor and employed in the particular industry to which the vote is given on the following valuation, viz.:—One vote for all such property up to £500 with an additional vote for every £500 or portion of £500 provided that no person shall be entitled to vote whose property under this clause amounts to less than £100 and that no person shall be entitled to more than six votes.

(3) The Commissioners may require from every voter and every candidate a declaration signed by the voter or candidate that he possesses the necessary qualifications and any voter or candidate who makes a false declaration in any material particular knowing it to be false shall be guilty of a misdemeanour and shall be liable on conviction on indictment to imprisonment for a term not exceeding two years.

(4) Companies or Corporations shall be entitled to vote on the same conditions and subject to the same regulations as hereinbefore expressed for individuals.

How vacancies in office of Commissioner to be filled up.

10. Any casual vacancy in the office of Commissioner occurring after the appointed day shall be filled up by the Corporation Society Association Company or persons by whom the Commissioner who filled the vacant office was chosen within one month after receiving notice of the vacancy and on failure so to do the Commissioners may fill up the vacancy but the person chosen to fill the vacancy must have the qualification by this Act required and shall be selected by the Commissioners from the class which his predecessor represented.

Payment of Commissioners.

11. The Commissioners shall be paid for their services under this Act out of the revenues accruing to them the sum of three guineas for each attendance of each member at their ordinary general special or committee meetings and such remuneration shall be paid to each member quarterly on the 1st day of December the 1st day of March the 1st day of June and the 1st day of September in every year.

Annal Retirement of Commissioners from office.

12. On the first Thursday in the month of September one thousand nine hundred and seven and on the first Thursday in the month of September in every subsequent year the Commissioners representing each of the classes or interests hereinafter mentioned shall go out of office and every Commissioner so going out of office shall be eligible for re-appointment.

Resignation of Commissioners.

13. Any Commissioner may resign his office by notifying his intention so to do in writing to the Clerk and any Commissioner appointed by or under the provisions of this Act who fails to attend the meetings of the Commission and to act in execution of this Act for three months unless incapacitated by illness shall be deemed to have refused to act and shall cease to be a Commissioner and any Commissioner dying resigning refusing to act or ceasing to possess the qualification prescribed by this Act shall be deemed to create a vacancy.

Quorum at Meetings and Committees.

14. The quorum of Commissioners at any meeting ordinary or special shall be twelve and the quorum of Commissioners at committee meetings shall be five.

Standing Orders of Commissioners.

15. Subject to the provisions of this Act the Commissioners may from time to time make alter and rescind standing orders bye-laws or regulations for ensuring order and uniformity in the conduct of business at meetings of the Commissioners and of their committees and for ensuring that due notice of business to be transacted at such meetings be given and as to the circumstances under and the manner in which their common seal is to be affixed or used and for regulation of their proceedings and business generally.

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Transfer of powers &c. of Thames Conservators in respect of the river below Teddington.

16. (1) Subject to the provisions of this Act as from the appointed day there shall be transferred to the Commission all rights powers and duties of the Conservators of the River Thames (in this Act referred to as " the Conservators ") in respect of the River Thames below Teddington Lock and there shall also be transferred from the Conservators to the Commission the lower navigation fund and all liabilities in respect of and any sinking fund applicable to the redemption of the Thames Conservancy Redeemable A Debenture Stock and all property and liabilities of the Conservators held acquired or incurred in respect of the Thames below Teddington Lock.

(2) All enactments relating to the Conservators (except those regulating the funds and accounts of and borrowing by the Conservators) shall as respects the rights powers duties property and liabilities transferred have effect as if references to the Commission were substituted for references to the Conservators ;

Provided that—

(*a*) in any such enactments references to the Port of London shall be construed as references to the tidal area as defined by this Act ;

(*b*) enactments relating to powers and duties as to steam launches house-boats and pleasure boats shall not apply to the Commission and in any such enactments for references to steam launches navigating above Kew Bridge there shall be substituted references to steam launches navigating above Teddington Lock ;

(*c*) in the definition of " the Thames " in section three of the Thames Conservancy Act 1894 for " from the entrance to Yantlet Creek in the County of Kent to the city stone opposite to Canvey Island in the County of Essex " there shall be substituted " from Warden Point in the County of Kent to the entrance of Havengore Creek in the County of Essex ; "

(*d*) in the proviso to sub-section (1) of section eighty-three of the Thames Conservancy Act 1894 (which relates to the area within which the powers of dredging are exerciseable) for the words " westward of a straight line drawn from the Shoeburyness water tower in the County of Essex to Eastchurch Church in the County of Kent " there shall be substituted the words " the estuary " as defined by this Act ;

(*e*) so much of the Thames Conservancy Act 1894 as exempts from duties of tonnage vessels trading coastwise between the Port of London and any place in Great Britain unless such vessel shall exceed forty-four tons tonnage and also vessels for passengers only shall be repealed ;

(*f*) the powers and duties of the Commission and their officers with respect to fishing boats fish and fishing shall not extend eastward of the line drawn from Yantlet Creek to the city stone opposite to Canvey Island unless the Board of Trade by Order so direct and if the Board of Trade make any such Order the Order may exclude from the Kent and Essex Sea Fisheries district any part of the Port of London included therein and for that purpose shall have effect as if it was an amending Order made under the Sea Fisheries Regulation Act 1888 ;

(*g*) Section 234 of the Thames Conservancy Act 1894 shall be suspended during the construction of the works authorised by this Act and repealed so far as the said works may when completed infringe upon the saving rights reserved by that section to the London Tilbury and Southend Railway.

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(3) Nothing in this section shall be construed as conferring on the Commission any right or interest in or to the shore or bed of the River Thames eastward of the said line drawn from Yantlet Creek to the city stone opposite to Canvey Island or as authorising the Commission except with the consent of the Board of Trade or the Commissioners of Woods to take use or in any manner interfere with or to authorise any person to take use or interfere with any portion of the bed or shore of the Thames eastward of the said line the management whereof is vested in the Board of Trade or the Commissioners of Woods and sections one hundred and sixteen and two hundred and thirty-nine of the Thames Conservancy Act 1894 shall not apply with respect to the Thames eastward of the said line but the Board of Trade and the Commissioners of Woods may transfer to the Commission upon such terms as may be respectively agreed on between them and the Commission any interest or right of His Majesty in right of His Crown in or to any portion of the shore or bed of the Thames between the said line and the line drawn from Warden Point to the entrance of Havengore Creek the management whereof is vested in them respectively.

Amendment of Act relating to the Conservators of the Thames.

17. (1) The Board of Trade may by Provisional Order make such amendments modifications and repeals of the enactments relating to the Conservators so far as they continue to apply to the Conservators after the appointed day as the Board may consider to be necessary in consequence of the passing of this Act and in particular any such Provisional Order may contain provisions for:—

(*a*) re-constituting the Conservators;

(*b*) requiring all payments received or made by the Conservators to be paid into or out of a single fund and charging on that fund all liabilities of the Conservators charged on either the lower navigation fund or the upper navigation fund and not by or under this Act transferred to the Commission;

(*c*) revising the tolls fees and other charges leviable by the Conservators.

(2) All moneys payable to the Conservators by the Metropolitan Water Board the West Surrey Water Company and the South West Suburban Water Company or their successors whether in pursuance of the Thames Conservancy Act 1894 or otherwise or of the Metropolitan Water Act 1902 shall be paid to the Conservators and no part thereof shall be paid to the Commission.

(3) The right of the Conservators to appoint a member of the Metropolitan Water Board shall be retained by the Conservators and shall not be transferred to the Commission.

Lands.

Power to take and use lands shown on the deposited plans.

18. Subject to the provisions of this Act the Commissioners may enter upon take and use such of the lands delineated upon the deposited plans and described in the deposited book of reference as may be required for the purposes of this Act.

Period for compulsory purchase of lands.

19. The powers of the Commissioners for the compulsory purchase of lands shall not be exercised after the expiration of three years after the appointed day.

Purchase of lands by agreement.

20. In addition to the other lands which the Commissioners are by this Act authorised to purchase and acquire they may purchase take on lease or acquire by agreement and may hold for the purposes of this Act any additional lands which they may deem requisite or convenient and any easements rights and interests in over or affecting such lands.

Persons under disability may grant easements &c.

21. Persons empowered by the Lands Clauses Acts to sell and convey or release lands may if they think fit subject to the provisions of those Acts and of this Act grant to the Commissioners any easement right or privilege (not being an easement right or privilege of water in which persons other than the grantors have an interest) required

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for the purposes of this Act in over or affecting any such lands and the provisions of the said Acts with respect to lands and rent-charges so far as the same are applicable in this behalf shall extend and apply to such grants or to such easements rights or privileges as aforesaid respectively.

Power to lease lands.

22. The Commissioners may from time to time after the completion of the works authorised by this Act grant leases of any of the lands acquired by them under the authority of this Act to any corporation company or person.

Terms and conditions of such leases.

23. Every such lease may be made for such term not exceeding ninety-nine years and with and subject to such exceptions reservations yearly or other rents or payments covenants conditions powers and provisions whatsoever as the parties thereto mutually agree on. Provided always that by every such lease due provisions shall be made for securing the payment performance and observance by the lessees thereunder of the rent (if any) covenants and provisions in and by the same respectively reserved and contained and on their part to be respectively paid performed and observed. Provided also that a duplicate or counterpart of every such lease shall be executed by the lessees therein named and be delivered to the Commissioners.

Works.

Power to construct works.

24. Subject to the provisions of this Act the Commissioners may make and maintain in the lines and situation and according to the levels shown upon the deposited plans and sections on lands in the Counties of Kent and Essex in and adjoining the River Thames delineated upon such plans and described in the deposited book of reference the dam and other works following that is to say:

A dam with locks weirs sluices gates roadway tunnel bridges approaches and other works in the Borough of Gravesend and in the Parishes of Milton and Chadwell shown on the deposited plans and sections commencing at a point 166 yards or thereabouts east of the south-eastern pier at the entrance gates to the Gravesend Town Pier in the Parish and Borough of Gravesend in the County of Kent and terminating at a point 100 yards or thereabouts in a south-easterly direction from the south-eastern corner of the World End public house in the Parish of Chadwell in the County of Essex.

Power to dredge, &c.

25. Subject to the provisions of this Act the Commissioners may within the limits of deviation shown on the deposited plans dredge scour and deepen the foreshore and bed of the river adjoining or near to any of the works by this Act authorised or for the purpose of obtaining access thereto and remove carry away and dispose of any chalk gravel or other substance taken up or collected by means of such dredging or scouring. Provided that the works authorised by this section below high-water mark shall not be commenced without the consent in writing of the Board of Trade.

Power to alter roads sewers &c.

26. For the purposes and during the execution of the several works which the Commissioners are by this Act authorised to make and in maintaining the same and subject to the provisions of this Act the Commissioners may from time to time cross stop up alter or divert any roads ways sewers drains pipes or other works upon or under any of the lands shown on the deposited plans and specified in the deposited book of reference with which they may from time to time find it expedient for any of those purposes so to interfere providing when possible a proper substitute before interrupting the traffic on any such road or way or the flow of water gas sewage or electricity in any such sewer drain pipe or other work and making full compensation to all persons injuriously affected by the exercise of the powers conferred upon them by virtue of this section. Provided that nothing in this section shall extend to authorise any

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interference with electric apparatus or other property of His Majesty's Postmaster-General or with the works of any undertakers within the meaning of the Electric Lighting Act 1882 to which the provisions of section 15 of that Act apply.

Certain works not to be deviated without consent of Board of Trade.

27. The Commissioners shall not make in over under through or across any tidal or navigable water any work by this Act authorised to be made or completed or deviate from the line of any such work as shown on the deposited plans in such manner as to avoidably diminish the navigable space, without the previous consent of the Board of Trade signified in writing under the hand of a secretary or assistant secretary and then only according to such plan and under such restrictions and regulations as the Board of Trade approve and where any such deviation or work is made with such approval the Commissioners shall not at any time alter or extend the same without first obtaining the like approval.

Limits of lateral and vertical deviation.

28. Except as by this Act otherwise provided in constructing the works authorised by this Act the Commissioners may deviate laterally to any extent within the limits of lateral deviation shown on the deposited plans and may deviate vertically from the levels shown on the deposited sections to any extent not exceeding five feet above and twenty feet below the levels so shown Provided that no deviation either lateral or vertical below high-water mark shall be made without the consent in writing of the Board of Trade.

Period for completion of works.

29. On the expiration of six years from the passing of this Act the powers by this Act conferred upon the Commissioners for constructing the dam weirs sluices locks and other works in this Act described shall cease except as to so much thereof as shall then be completed.

Lights on works.

30. The Commissioners shall on or near the works below high-water mark hereby authorised during the whole time of the constructing altering or extending the same exhibit and keep burning at their own expense every night from sunset to sunrise such lights (if any) as the Board of Trade from time to time require or approve. If the Commissioners fail to comply in any respect with the provisions of this section they shall for each night in which they so fail be liable to a penalty not exceeding twenty pounds.

Provision against danger to navigation.

31. In case of injury to or destruction or decay of the dam or works or any part thereof the Commissioners shall lay down such buoys exhibit such lights or take such other means for preventing so far as may be danger to navigation as shall from time to time be directed by the Board of Trade and shall apply to the said Board for directions as to the means to be taken and the Commissioners shall be liable to a penalty not exceeding ten pounds for every month during which they omit so to apply or refuse or neglect to obey any direction given in reference to the means to be taken.

Various Powers.

Transfer of certain powers and duties of the Watermen's Company and provisions as to lightermen.

32. (1) Subject to the provisions of this Act as from the appointed day there shall be transferred to the Commission all powers and duties of the Watermen's Company and of the Court of Master Wardens and Assistants of the Watermen's Company (in this Act referred to as "the Court of the Watermen's Company") with respect to—

(*a*) the registration and licensing of crafts and boats;

(*b*) the licensing of lightermen and watermen; and

(*c*) the government regulation and control of lightermen and watermen (including the appointment of plying places and of inspectors);

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and there shall also be transferred from the Company to the Commission all property and liabilities of the Company held acquired or incurred by the Company in connexion with the powers and duties so transferred:

Provided that—

(*a*) the qualifications to be possessed by applicants for lightermen's and watermen's licences and the conditions on which such licences are to be granted or renewed shall be such as the Commission may by bye-laws prescribe;

(*b*) it shall be lawful for the Commission to make a bye-law providing that notwithstanding any enactment to the contrary craft or any class of craft when not carrying passengers may be worked or navigated within the Port of London or any part thereof without having any licensed lighterman or other specially qualified person in charge thereof; and

(*c*) nothing in this section shall be construed as transferring to the Commission the Watermen's Hall or the sum of six thousand seven hundred and forty-one pounds Consolidated two-and-a-half per cent. Stock standing in the name of the Company or the freehold property known as Nos. 16 and 17 St. Mary Hill in the Parish of Billingsgate in the City of London or any property held for charitable purposes.

(2) All enactments relating to the Watermen's Company and the Court of the Watermen's Company shall so far as not repealed by this Act and so far as they relate to the powers and duties transferred have effect as if references to the Commission were substituted for references to the Company and to the Court:

Provided that—

(*a*) an appeal shall not lie to a court of summary jurisdiction against a refusal by the Commission to register any craft or boat or against the revocation by the Commission of any certificate or licence relating to any craft or boat;

(*b*) so much of any such enactment as limits the fees which may be imposed in respect of the registration or licensing of craft and boats shall be repealed but the fees so imposed shall not exceed such as may be allowed by any provisional Order made for the purpose by the Board of Trade; and

(*c*) So much of any such enactment as exempts river steamboats from being registered shall be repealed.

(3) Every person possessing such qualifications as the Court of the Watermen's Company may by bye-laws prescribe shall as from the appointed day be qualified to be elected a freeman of the Company.

Provisions as to Sunday ferries and other charities of the Watermen's Company.

33. (1) So much of the Watermen's and Lightermen's Amendment Act 1859 as relates to Sunday ferries and the appointment and licensing of watermen or lightermen to ply on Sundays shall as from the appointed day be repealed and the Commission shall pay to the Watermen's Company in respect of any Sunday ferry established under that Act and existing at the passing of this Act such sum as in default of agreement may be determined by arbitration.

(2) Penalties and forfeitures paid to the Commission under section ninety of the Watermen's and Lightermen's Amendment Act 1859 as applied by this Act shall be applied by the Commission as part of their general funds and the Commission shall pay to the Watermen's Company in respect of the loss of such penalties and forfeitures such sum as failing agreement may be determined by arbitration.

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(3) The sums to be so paid to the Watermen's Company shall be paid into and form part of and be held on the trusts affecting the Poor's Fund of the Watermen's Company.

(4) If the Charity Commissioners are at any time of opinion that by reason of any alteration in the constitution or nature of the Watermen's Company or the qualifications to be possessed by freemen the trusts affecting the Poor's Fund of the Company require to be modified the Charity Commissioners may either on the application of the Watermen's Company or without any such application establish a scheme under the Charitable Trusts Acts 1853 to 1894 regulating the application and administration of the Poor's Fund regard being had to the purposes to which that fund is at the passing of this Act applicable.

(5) Arbitrations under this section shall be in accordance with the provisions of the Arbitration Act 1889 and the provisions of this Act as to arbitrations under this Act shall not apply.

Compensation to Officers and Servants.

34. Subject to the provisions of this Act every officer and servant of the Thames Conservancy and the Watermen's Company immediately before the appointed day employed upon or in connection with such portion of the Thames as is by this Act subject to the jurisdiction of the Commissioners (in this section referred to as " existing officer " and " existing servant ") and not being continued in the employment of the Thames Conservancy or of the Watermen's Company respectively shall as from the appointed day become a servant or officer of the Commissioners and shall hold his office or situation by the same tenure and upon like terms and conditions as he would have held the same if this Act had not been passed and while performing the same duties shall receive not less salary wages or payment than he would have been entitled to if this act had not been passed. Provided the Commissioners may abolish the office or situation of any existing officer or existing servant which they may deem unnecessary every existing officer or existing servant whose office or situation is so abolished or who otherwise suffers any direct pecuniary loss in consequence of this Act shall be entitled to be paid compensation by the Commissioners for such pecuniary loss. Such compensation shall be determined by the Arbitration Board under this Act. Subject to the provisions of this section the Arbitration Board in awarding such compensation shall proceed in accordance with the scale of compensation provided by Section 120 of the Local Government Act 1888 and the Treasury rules incorporated thereby.

Commissioners may provide steam-dredgers and other machinery.

35. The Commissioners from time to time may build purchase hire provide and use vessels to be worked by steam or otherwise at their discretion for dredging scouring cleansing and deepening the bed of the harbour and the approaches thereto within the tidal area as defined by this Act.

Power to remove offal and to deal with pollution.

36. The Commissioners shall have power to make bye-laws as to the disposal of refuse and offal of all kinds from vessels using the Thames Harbour and the Docks connected therewith and as to the pollution of the Thames Harbour by masters or owners of vessels or by owners or occupiers of docks or waterside premises and such bye-laws shall have force as bye-laws made in pursuance of this Act and they may themselves collect offal and refuse from vessels in the Thames Harbour or Docks and carry the same to the Barrow Deep or to sea and there discharge the same. For this purpose the Commissioners may from time to time build purchase hire provide and use vessels to be worked by steam or otherwise at their discretion and they may charge the masters or owners of vessels from which offal or refuse is so removed by them such rates for the services rendered as the Board of Trade may approve. Provided that nothing contained

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in this Section shall limit or control the powers of the Corporation under Section 291 of the Public Health Act 1875 or any Act amending the same as the Port Sanitary Authority.

Control of level and flow of river.

37. The Commissioners shall control the permanent mean level of water to be maintained within the Thames Harbour and raise or lower same from time to time as they may deem expedient and advantageous and shall control the flow of the river and the working of the sluices locks scouring sluices and the movable bridges across the said locks in accordance with rules and regulations copies of which shall be supplied to all applicants and be conspicuously posted in convenient positions at each end of the roadway across the dam and at or about the middle thereof and in all riverside public stairs piers jetties and docks. Such rules and regulations shall be drawn up by the Commissioners and shall have been submitted to and approved by the Board of Trade before being put in force and shall have force as bye-laws made under the provisions of this Act.

Transfer to Commissioners of certain powers of Trinity House.

38. As and from the appointed day all the powers, rights and authorities conferred upon the Trinity House under the provisions of the Merchant Shipping Act 1894 (Parts 10 & 11) so far as the same apply to pilotage and lighthouses within the Thames Harbour are hereby transferred to and shall be exercisable by the Commissioners.

Agreement as to supply of water for power and manufacturing purposes.

39. The Commissioners may enter into and carry into effect Agreements with any corporation, company or person requiring the same for manufacturing power or other purposes for the sale to them of water from the river between Teddington Weir and the Dam at Gravesend at such price and subject to such conditions as the Commissioners may think fit.

Bye-laws for watermen labourers &c.

40. The Commission shall draw up a complete set of bye-laws for the regulation of the licensing hire payment and employment of watermen labourers and all persons publicly plying for hire within the Thames Harbour and such bye-laws and all additions or amendments of same shall be made and have force as bye-laws made under this Act.

Water Police.

41. The Commissioners may provide a sufficient number of Water Police with boats and launches to patrol the Thames Harbour and maintain order such police to be appointed under the provisions of Sections 79 and 80 of the Harbours Docks and Piers Clauses Act 1847.

Power to acquire Dock Water areas.

42. The Commissioners may enter into Agreements with any of the Dock Companies or other owners of Docks for the acquisition of the partial or entire control of the water areas of such Docks and of the entrances thereto and channels connecting the same and may in return for the transference to them of such control of such water areas guarantee to the owners of such water areas the payment of interest not exceeding three-and-a-half per centum on the capital value of such water areas as may be settled by Agreement or by the Board of Arbitration to be constituted under this Act.

Provided that the Commissioners shall not have power under this Section to acquire control over any wharves quays or land abutting on the water areas of the Docks except such wharves quays or land as may be necessary to enable them to enlarge or deepen the entrances to the said water areas or the said channel;

Provided further that the sanction of the Board of Trade shall have been obtained to the acquisition by the Commissioners under this Section of any such wharves quays or land; and

Provided further that any water areas over which the Commissioners may obtain control under this Section shall from the time they pass under the control of the Commissioners form part of the Thames Harbour and shall be subject to all the rules regulations or bye-laws which under this Act or any Act incorporated therewith may be applicable to the said Harbour.

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Power to reclaim.

43. The Commissioners may from time to time construct walls quays or embankments below high-water mark for the purpose of reclaiming land and may fill in the area behind such walls quays or embankments and the areas so reclaimed shall be under the complete control of the Commissioners who shall have power to sell lease or otherwise deal with the same as they may think fit and may strengthen any part of the river walls protecting low-lying lands where they think necessary from time to time.

Provided that the Commissioners shall not so reclaim any land from the Thames without the sanction of the Board of Trade except for the purpose of strengthening the river walls or for drainage works;

Provided also that the Commissioners shall before reclaiming any land from the Thames under this Section have acquired by agreement or arbitration under this Act the water landing and other rights of the owners of land adjoining the river whose access to the river will be cut off or injuriously affected by such reclaiming of the river bed; and

Provided also that nothing in this Section shall empower the Commissioners to establish wharves or to undertake the business of wharfingers except for their own goods material or plant on the land so reclaimed.

Agreements with Companies.

44. The Commissioners may enter into and carry into effect Agreements with Dock Shipping Wharf Railway Water or other Companies or Corporations affected by this Act for any purposes that they may deem expedient for the improvement maintenance or traffic of the Thames Harbour or of any approaches thereto.

Power to collect tolls for user of tunnel.

45. The Commissioners shall have power to charge such tolls as may be fixed by the Board of Trade on all traffic passing through the tunnel authorised by this Act.

Compensation.

46. The Commissioners shall compensate out of the funds provided by this Act and out of the revenues of the Thames Harbour :—

(*a*) All persons whose lands buildings or works are shown to be injuriously affected by the maintenance of a permanent water level in the said Harbour;

(*b*) All persons whose lands are damaged by flooding due directly to leakage from the said Harbour;

(*c*) All drainage authorities who at the date of the passing of this Act exercise any legal powers of drainage into the Thames Harbour whose drains sluices and other structures are damaged or obstructed by the maintenance of a permanent water level in the said Harbour;

(*d*) All officials of the Thames Conservancy Board and the Watermen's Company as provided by the Section of this Act whereof the marginal note is "Compensation to Officers and Servants."

Arbitration Board.

47. The amount and nature of such compensation shall be determined by an Arbitration Board to consist of three members nominated one by the London County Council one by the Corporation of the City of London and one by the Board of Trade.

Meetings of Arbitration Board.

48. The Arbitration Board shall hold such meetings as it may deem necessary and hear evidence on oath from all parties as shall appear to the Board to be concerned and its decision shall be final and binding upon the parties and the Arbitration Board shall have full discretion as to costs.

Payment of Arbitration Board.

49. The members of the Arbitration Board shall be paid such fees as the Board of Trade may approve out of the funds at the disposal of the Commissioners.

Improvement in value.

50. The Arbitration Board shall make due allowance in all cases for any improvement in value of properties which may be injuriously affected or damaged as aforesaid

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provided that such improvement in value is due to the said maintenance of a permanent water level in the said Harbour or otherwise to the operation of this Act.

Pumping low lands.

51. Where the claim is for damage by flooding or damage to drainage work due to the level of the land being too low to drain into the Thames Harbour it shall be competent for the Commissioners to provide pumping engines or other mechanical means for raising the drainage water and discharging the same into the said Harbour.

Sewage &c. not to be pumped.

52. The Commissioners shall not be compelled to pump and discharge sewage or manufacturing effluents which would cause pollution of the Thames Harbour unless such sewage or effluents have been first effectually clarified and filtered by the owners thereof.

Utilisation of surplus water for locking or scouring purposes.

53. The Commissioners may use for locking or scouring purposes the surplus water of the harbour at Gravesend or such of it as may not be required.

Buoyage.

54. The Commissioners shall lay down buoys for the guidance of vessels in such situations and of such character as they may determine within the limits of the Thames Harbour.

Erection of pumping stations.

55. The Commissioners may construct and work pumping stations at any point on the Thames Harbour where it is found necessary to raise the drainage water to a higher level than its natural flow in order to discharge it into the said Harbour above the permanent mean water level.

Bye-laws.

56. All bye-laws made in pursuance of this Act shall be made with the formalities and subject to the same conditions in all respects as to bye-laws as are provided in the Commissioners Clauses Act 1847 or the Thames Conservancy Act 1894. Provided that no bye-law nor the repeal or alteration of any bye-law under the said Acts shall be of any effect unless confirmed by the Board of Trade.

Harbour-Masters and other Officers.

Appointment of harbour-masters and other officers.

57. The Commissioners may from time to time appoint such harbour-masters pier-masters and other officers and servants as the Commissioners deem requisite for the execution of the several purposes of this Act and upon such terms and conditions as the Commissioners may approve.

Officers may be suspended.

58. The Commissioners may at any time suspend any officers in their employment and may appoint another person temporarily to fill any office under them which may be vacant from any cause.

Any appointment suspension or removal of an officer by the Commissioners may be made by resolution of the Commissioners passed at a meeting of the Commissioners.

Rates and Dues.

Rates on vessels as in First Schedule.

59. The Commissioners may from time to time subject to the provisions of this Act in addition to the tonnage dues which the Commissioners may demand and take from vessels entering or clearing outward from the Port of London under the provisions of the Thames Conservancy Acts as varied by this Act demand and take in respect of all vessels passing upwards or downwards through the locks or dam of the Thames Harbour any sum not exceeding the several rates and sums specified in that behalf in the first Schedule hereto and every such sum shall be paid by the master of the vessel and in the case of fishing boats steamers and other vessels trading to and from or frequently using the said Harbour the Commissioners may agree to charge such annual or other sum as they may think reasonable by way of compounding for the rates or sums payable in respect of such vessels.

60. The Commissioners from time to time may subject to the provisions of this Act demand and take in respect of the goods or stores discharged from or loaded into any vessel entering inwards from over the seas or clearing outwards to over the seas to or from the Thames Harbour any sums not exceeding the sums specified in that

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behalf in the Second Schedule to this Act and every such sum shall be paid by the owner consignee or shipper of such goods or stores provided that no rate shall be charged on ship's stores for the use of the ship or on bunker coal or on goods or stores required for the use of the Crown and provided that the rates so charged by the Commissioners shall at all times be charged equally to all persons in respect of the same description of goods.

Financial.

Power to borrow on mortgage.

61. The Commissioners may from time to time borrow upon the security of the rents rates dues tolls and charges which they are authorised to demand and take under the provisions of this Act and the other revenues of the Commissioners such sums as they may deem necessary for the purposes of this Act not exceeding five millions sterling.

Application of borrowed money.

62. All moneys to be borrowed by the Commissioners under the authority of this Act shall be applied by them to all or some of the purposes in the order following:—

(1) In payment of all costs charges and expenses of and incidental to the preparing obtaining and passing of this Act and otherwise in relation thereto and in payment of the reasonable expenses of the Thames Barrage Committee and their officials;

(2) In payment of the expenses incurred by the Commissioners in the purchase or acquisition of lands or other proprietary interests in the payment of compensation under this Act and in the construction of the works and plant authorised by this Act and otherwise in relation thereto;

Provided that any dispute as to the amount due from the Commission for such preliminary costs charges and expenses shall be referred to the Arbitrators constituted under this Act; and

Provided that the Commissioners may for a period not exceeding four years during the construction of the works pay interest upon mortgages at a rate not exceeding three per centum such interest to accrue due during the period limited for the construction of the works authorised by this Act out of the moneys borrowed on mortgage.

Application of rents rates &c.

63. All moneys from time to time arising from any rents rates tolls dues and charges payable to the Commissioners and from other revenues of the Commissioners not being borrowed moneys shall be applied by them to all or some of the purposes and in the order following (that is to say):—

(1) In payment of all expenses incurred by the Commissioners in the maintenance and repair of the works by this Act authorised and in payment of all expenses incurred in the management of the harbour in remunerating the officers and servants of the Commissioners in defraying law charges and all other necessary expenses incurred by the Commissioners in carrying this Act into execution not properly chargeable to capital account;

(2) In payment so long as it remains payable of interest on any Debenture Stock Debentures Mortgage Debts and other Charges the liability for which is by this Act transferred to the Commission;

(3) In payment of interest upon mortgages granted by the Commissioners under the authority of this Act;

(4) In paying any interest guaranteed to Dock or other companies for the acquisition of any Dock water areas by the Commission under the provisions of this Act;

(5) In providing a sinking fund as hereinafter provided;

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(6) In making and maintaining such other improvements in the Thames Harbour and generally in executing and maintaining such works in connection therewith within the limits of this Act as to them shall seem fit;

(7) In the reduction of the rates tolls dues and charges by this Act authorised to be levied by the Commissioners;

Provided that any moneys payable to the Commissioners under the provisions of the Thames Conservancy Acts and allocated by those Acts to specific purposes shall be applied to such specific purposes

Money may be borrowed in substitution of sums paid off.

64. In case any part of the money raised or borrowed by the Commissioners on the security hereinbefore authorised shall at any time be called up or be paid off and discharged otherwise than by the sinking fund hereinafter provided it shall be lawful for the Commissioners from time to time to borrow and take up at interest on the same security any sum in lieu of such part of the said debt as shall have been so called up or paid off and discharged.

Lenders not to be required to see to application of money.

65. Any person lending money to the Commissioners shall not be bound to inquire as to the application or be answerable for any loss or misappropriation of such money or any part thereof.

Sinking Fund.

66. On the expiration of two years after the appointed day the Commissioners shall set apart and appropriate annually out of the rents rates dues tolls and charges arising by virtue of this Act as a sinking fund to be applied in paying off the principal sums from time to time borrowed under this Act a sum equal to two per centum of the balance remaining unpaid of the sums borrowed such sums to be invested in the purchase of any securities in which trustees are for the time being authorised to invest and to be increased by accumulation in the way of compound interest or otherwise and every three years this accumulated fund shall be used to pay off mortgages as provided in Section 85 of the Commissioners Clauses Act 1847.

Commissioners to make return to Board of Trade as to Sinking Fund.

67. The clerk to the Commissioners shall within twenty-one days after the expiration of each year during which any sum is required to be set apart for a sinking fund under this Act transmit to the Board of Trade a return in such form as may be prescribed by that Board and verified by statutory declaration if so required by them showing the amount which has been invested for the purpose of such sinking fund during the year preceding the making of such return and the description of the securities upon which the same has been invested and also showing the purposes to which any portion of the moneys invested for the sinking fund and the interest thereof have been applied during the same period and the total amount remaining invested at the end of the year. And in the event of any wilful default in making such return such clerk shall be liable to a penalty of not exceeding twenty pounds. If it appear to the Board of Trade by such return or otherwise that the Commissioners have failed to set apart the sum required by this Act for the sinking fund or have applied any portion of the moneys set apart for that fund or any interest thereof to any purposes other than those authorised by this Act the Board of Trade may by order direct that a sum not exceeding double the amount in respect of which such result shall have been made shall be set apart and invested as part of the sinking fund and such order may be enforced by writ of mandamus to be obtained by the Board of Trade out of the High Court.

Application of provision of Merchant Shipping Act.

68. Save in so far as a contrary intention is expressed in this Act nothing in this Act contained shall be deemed to exempt the Thames Harbour or the Commissioners from the provisions of the Merchant Shipping Act 1894 or any Act amending the same or any general Act relating to harbours or docks or dues on shipping or on goods carried in ships now in force or which shall be passed during the present or any future

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session of Parliament or from any future revision and alteration under the authority of Parliament of the rates authorised by this Act.

Works below high-water mark not to be commenced without consent of Board of Trade.

69. The Commissioners shall not under the powers of this Act construct on the shore of the sea or of any creek bay arm of the sea or navigable river communicating therewith where and so far up the same as the tide flows and reflows any work without the previous consent of the Board of Trade to be signified in writing under the hand of one of the secretaries or assistant secretaries of the Board of Trade and then only according to such plan and under such restrictions and regulations as the Board of Trade may approve such approval being signified as last aforesaid and where any such work may have been constructed the Commissioners shall not at any time alter or extend the same without obtaining previously to making any such alteration or extension the like consents or approvals If any such work be commenced or completed contrary to the provisions of this Act the Board of Trade may abate and remove the same and restore the site thereof to its former condition at the costs and charges of the Commissioners and the amount of such costs and charges shall be a debt due from the Commissioners to the Crown and shall be recoverable as a Crown debt or summarily.

Survey of work by Board of Trade.

70. If at any time the Board of Trade deems it expedient for the purposes of this Act to order a survey and examination of a work constructed by the Commissioners on in over through or across tidal lands or tidal water or of the intended site of any such work the Commissioners shall defray the expense of the survey and examination and the amount thereof shall be a debt due from the Commissioners to the Crown and be recoverable as a Crown debt or summarily.

Abatement of work abandoned or decayed.

71. If a work constructed by the Commissioners on in over through or across tidal lands or tidal water is abandoned or suffered to fall into decay the Board of Trade may abate and remove the work or any part of it and restore the site thereof to its former condition at the expense of the Commissioners and the amount of such expense shall be a debt due from the Commissioners to the Crown and be recoverable as a Crown debt or summarily.

Crown Rights.

72. Nothing contained in this Act shall authorise the Commissioners to take use or in any manner interfere with any portion of the shore or bed of the sea or of any river channel creek bay or estuary or any land hereditaments subjects or rights of whatsoever description belonging to His Majesty in right of His Crown and under the management of the Commissioners of Woods or of the Board of Trade respectively without the previous consent in writing of the Commissioners of Woods or of the Board of Trade as the case may be on behalf of His Majesty first had and obtained (which consent the said Commissioners and Board are hereby respectively authorised to give).

Expenses of Act.

73. All costs charges and expenses of and incident to the preparing for obtaining and passing of this Act or otherwise in relation thereto shall be paid and discharged out of the funds of the Commissioners.

[SCHEDULES

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SCHEDULES REFERRED TO IN THE FOREGOING ACT.

First Schedule.

	£	s.	d.
On all registered vessels passing through the Locks at Gravesend either up or down being over 10 tons register and not being fishing vessels per registered ton	0	0	1
On fishing vessels per registered ton	0	0	0½
On all vessels below 10 tons register per vessel the sum of	0	0	6
On all unregistered vessels passing through the Locks at Gravesend either up or down, being over 10 tons, per ton measurement	0	0	1½

The above rates shall not be charged upon any vessel of His Majesty's ships or any vessels the property of the Trinity House or of the Corporation or of the London County Council.

Second Schedule.

1. Subject to the provisions of this Act the rate on goods imported from parts beyond the seas into the Thames Harbour or exported from the said Harbour to parts beyond the seas shall be such rates as the Commissioners may fix subject to the approval by the Board of Trade by Provisional Order.

2. The above rates shall not be chargeable on ship's stores for the use of the vessel carrying them or on bunker coal or on goods or stores the property of the Crown or of the Trinity House.

3. No rate shall be charged on goods under the provisions of this Schedule until the appointed day.

4. The rates under this Schedule shall not apply to goods discharged from any vessel entering from over the seas and re-loaded on another vessel for export to parts beyond the seas.

5. Where any vessel shall enter the Thames Harbour from any place coastwise but shall discharge within the area of the Harbour goods which the said vessel has brought from parts beyond the seas the rates specified in this Schedule shall be chargeable on such goods as if the vessel had entered the said Harbour direct from parts beyond the seas.

6. Where goods are exported from the Thames Harbour to a place coastwise and thence exported to parts beyond the seas then in any such case the authority having jurisdiction in the port of such place coastwise shall if so required by the Commissioners collect and pay over to the Commissioners the rates to which the goods would have been liable had they been exported direct and for that purpose such authority shall have all such powers of collecting rates as the Commissioners may have under the provisions of this Act.

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